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MACHINE LEARNING APPROACH FOR EVAPORATION DUCT NOWCAST

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THESIS

MACHINE LEARNING APPROACH FOR EVAPORATION DUCT NOWCAST

by

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June 2021

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The Evaporation Duct Height (EDH) and Strength (EDS) are properties of the evaporation duct that affects electromagnetic (EM) signal propagation close to the air-sea interface. Hence, the accuracies of EDH and EDS affect radar and communication propagation, which can be exploited for detection and counter-detection operations. The EDH/EDS can be calculated utilizing meteorological and oceanographical (METOC) data collected onboard naval ships, including air temperature, sea surface temperature, wind direction, wind speed, sea level pressure, and relative humidity. In this work, we explore the utilization of artificial intelligence/machine learning (AI/ML) algorithms to demonstrate the feasibility to nowcast (up to six-hour forecast) EDH/EDS while a naval vessel is underway. The tested AI/ML algorithms include linear regression, decision trees, random forest, and neural networks. Datasets from the 2017 Coupled Air-Sea Processes and Electromagnetic Ducting Research (CASPER-West) project were used to train, test, and verify the predictions from the AI/ML algorithms. Two methods to forecast EDH/EDS are tested—one to forecast EDH/EDS directly, the other to calculate EDH/EDS based on the AI/ML forecast variables as input to NAVSLaM. The results are compared to those directly derived from the CASPER measurements. The effectiveness and limitations of the methods and algorithms are discussed.

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MACHINE LEARNING APPROACH FOR EVAPORATION DUCT NOWCAST

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requirements for the degree of

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The Evaporation Duct Height (EDH) and Strength (EDS) are properties of the evaporation duct that affects electromagnetic (EM) signal propagation close to the air-sea interface. Hence, the accuracies of EDH and EDS affect radar and communication propagation, which can be exploited for detection and counter-detection operations. The EDH/EDS can be calculated utilizing meteorological and oceanographical (METOC) data collected onboard naval ships, including air temperature, sea surface temperature, wind direction, wind speed, sea level pressure, and relative humidity. In this work, we explore the utilization of artificial intelligence/machine learning (AI/ML) algorithms to demonstrate the feasibility to nowcast (up to six-hour forecast) EDH/EDS while a naval vessel is underway. The tested AI/ML algorithms include linear regression, decision trees, random forest, and neural networks. Datasets from the 2017 Coupled Air-Sea Processes and Electromagnetic Ducting Research (CASPER-West) project were used to train, test, and verify the predictions from the AI/ML algorithms. Two methods to forecast EDH/EDS are tested—one to forecast EDH/EDS directly, the other to calculate EDH/EDS based on the AI/ML forecast variables as input to NAVSLaM. The results are compared to those directly derived from the CASPER measurements. The effectiveness and limitations of the methods and algorithms are discussed.

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LIST OF ACRONYMS AND ABBREVIATIONS

ABL	atmospheric boundary layer
AI	artificial intelligence
APM	Advanced Propagation Model
ARIMA	Automated Regression Integrated Moving Average
AREPS	Advanced Refractive Effects Prediction System
CASPER	Coupled Air-Sea Processes and Electromagnetic ducting Research
COAMPS	Coupled Ocean/Atmosphere Mesoscale Prediction System
COARE	Coupled Ocean-Atmosphere Response Experiment
DT	decision tree
DTR	decision tree regressor
EDH	evaporation duct height
EDM	evaporation duct model
EDS	evaporation duct strength
EM	electromagnetic
EMW	Electromagnetic Maneuver Warfare
FLIP	Floating Instrument Platform
FLOP	FLIP's lowest observing platform
GPC	great power competition
GPS	Global Positioning System
GUI	graphical user interface
LR	linear regression
MABL	marine atmospheric boundary layer
MAE	mean absolute error
MAPE	mean absolute percentage error
MAPS	Marine Atmospheric Profiling System
MASL	maritime atmospheric surface layer
METOC	meteorological and oceanographic
ML	machine learning
MOST	Monin–Obukhov Similarity Theory
MSE	mean squared error

NaN	not-a-number
NAVSLaM	Navy Atmospheric Vertical Surface Layer Model
NOAA	National Oceanic and Atmospheric Administration
ONR	Office of Naval Research
RF	random forest
RFR	random forest regressor
RMSE	root mean squared error
R/V	research vessel
RVSR	Research Vessel Sally Ride
TF	TensorFlow

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I am very thankful for all the support received for this thesis, even throughout all the issues with COVID-19 and the 2020 California fires. The popular sentiment and phrase of “this too shall pass” was ever present. To all my new-found lifelong friends, and to Kristina, I am very thankful for the conversations and great advice throughout these last few months.

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I. INTRODUCTION

In the current geopolitical environment of renewed great power competition, it has become increasingly important to establish awareness of the physical environment of the battlespace. That means that we must be able to find, describe, and exploit the areas where assets can be hidden or detected. As such, different technologies in radar and other remote sensing equipment have been developed by all modern militaries. In order to understand these areas, different models for electromagnetic propagation have been developed throughout the decades. All of these models require observations of ambient air temperature, sea surface temperature, atmospheric pressure, relative humidity, and wind speed (Bean and Dutton 1968).

The U.S. Navy has utilized several tactical decision aids (TDAs) to describe and exploit electromagnetic (EM) propagation for the employment of radar, and other weapons systems. These TDAs require input from atmospheric and oceanographic models, which are run ashore. The most widely utilized model for EM TDAs in the U.S. Navy is the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS), since it provides parameter values at relatively high spatiotemporal resolution. Significant computing power is required to run COAMPS to attain all the parameters needed for a high-resolution EM propagation related forecast. Then that forecast run ashore must be distributed via electronic communications to afloat units, several times a day as models are updated. A broken link in the electronic communication chain can severely hamper at-sea operations, either by many possible complications with satellite communications, landline issues, or an emissions condition (EMCON) set by a particular ship, which would mean that the information would not be received by the intended user.

It has become apparent that all aspects of warfare have been interwoven by networks. Within these networks, the utility of using different parts of the electromagnetic spectrum (EMS), and its management for use and exploitation, needs to be accurately forecast and (even more so), and that forecast received and understood by all parties who utilize this information (Esper 2020).

> In today's crowded electromagnetic spectrum and increasingly networked systems, we must understand the terrain of the electromagnetic spectrum and exploit that high ground to our overwhelming advantage. It's one more way that Naval Oceanography provides the home-field advantage to the fleet's away games. Rear Adm. Tim Gallaudet (Naval Oceanography Releases Electromagnetic Maneuver Warfare Strategy 24 March 2016). (U.S. Office of Information 2016)

Three major goals were selected in the Electromagnetic Maneuver Warfare (EMW) 2016 strategy of the Naval Meteorology and Oceanography Command:

1. Influence development of the Navy's electromagnetic maneuver warfare capabilities
2. Improve Naval Oceanography's environmental sensing and prediction capabilities
3. Integrate electromagnetic environmental impacts into the Navy's decision-making process. (Gallaudet 2016)

This thesis' focus is on the efforts toward the second goal. Specifically, the objective is to explore the feasibility of techniques to use shipboard computational assets, and simple and relatively well-established machine-learning approaches to calculate evaporative duct height (EDH)/evaporative duct strength (EDS) in an at-sea standalone environment. Such a capability, if sufficiently accurate, will considerably increase the surface navy's self-reliance during operations in a communication denied environment, or during a communications outage.

We focus our examination of EM propagation on EDH and EDS, since these are the key parameters in calculating EM propagation in the atmospheric boundary layer (ABL), where ships operate. We focus on short term forecasting (< 6 hours), as these forecasts may be amenable to statistical techniques. We have chosen artificial intelligence/machine learning (AI/ML), since these techniques are becoming ubiquitous with many algorithms "on the shelf," able to be run on a laptop/desktop, and without the need for expensive high computing equipment.

The application of AI/ML is not intended to be a substitute for the information given by the more rigorous physics-based numerical weather prediction (NWP) models, but is to be utilized in the event of a communications outage, as part of shipboard training for self-reliance, as well as possible "corrections" to the NWP models, since the in-situ

information derived from the AI/ML approach may be more representative of the current situation or location for a particular asset than the volume averaged output from even high resolution NWP forecasts. As such, one potential capability for all naval assets is to generate EDH/EDS nowcast, defined by the National Oceanic and Atmospheric Administration (NOAA) as “a short-term weather forecast, generally out to six hours or less. This is also called a Short-Term Forecast” (NOAA 2009). Naval assets already collect the atmospheric and oceanic parameters needed as input for this calculation, and in the event of a communication outage, naval assets could use AI/ML to be self-reliant for EDH/EDS forecasts. Additionally, naval assets record other datasets potentially useful for a variety of forecasts using AI/ML approaches.

Empirical methods have been, and continue to be, used by weather forecasters. At a minimum these methods provide a fast check on many forecasts. Forecasting rules have been developed from both empirical methods and physics understanding (e.g. the shifting of winds signals an approaching front or front passage, or the drop of sea level pressure by a threshold amount in a 12-hour or 24-hour period signals an approaching low-pressure system, etc). The development of AI/ML based nowcasting algorithms for EDH/EDS is a natural extension of such empirical rules.

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II. BACKGROUND

A. REFRACTIVE CONDITIONS IN THE ATMOSPHERE

Communication and the use of active and passive sensors for contact detection are critical components of naval operations. Radar detections and communications between naval assets are affected by EM ducting, a phenomenon caused by decreasing humidity with height above the sea surface (Babin et al. 1997). The warfighter will be able to better exploit EM propagation by having accurate predictions of the EDH (Wang et al. 2018).

EM signals bend as they travel through the atmosphere when the index of refraction changes with height. The radio refractive index, *N*, is defined as (Bean and Dutton 1966):

$$N = (n - 1) \times 10^6$$

where *n* is the index of refraction. *n* can be calculated by the air pressure, temperature, and vapor pressure as shown in the following equation (Turton et al. 1988, Bean and Dutton 1966):

$$N = 77.6 \frac{P}{T} - 5.6 \frac{e}{T} + (3.75 \times 10^5) \frac{e}{T^2}$$

where *P* is atmospheric pressure in hectopascals, *e* is water vapor pressure in hectopascals, and *T* is the temperature in Kelvin. In a standard atmosphere, the path for an EM signal is bending downward due to the vertical gradient of refractivity (Figure 1 from Turton et al. 1988).

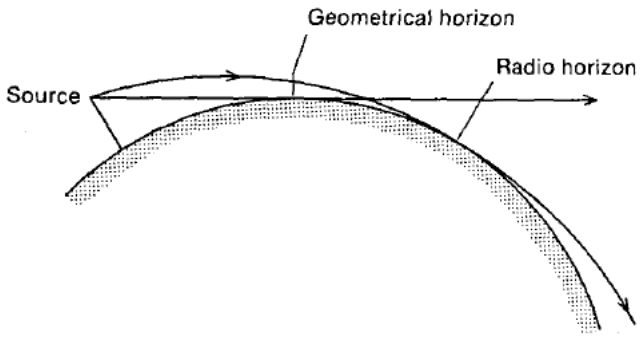


Figure 1. Schematic diagram illustrating the bending of a radio wave beyond the geometric horizon due to atmospheric refraction (vertical scale greatly exaggerated). Source: Turton et al. (1988).

The most frequently used variable to describe the refraction of EM waves relative to the Earth's curvature is the modified refractivity *M*,

$$M = N + \frac{z}{r_e \times 10^{-6}} = N + 0.157z$$

which is a dimensionless quantity, where r_e is the radius of earth ($\approx 6.378 \times 10^6$ m) and z is the height above the surface in meters (Babin et al. 1997).

In a standard atmosphere, N decreases with height, and M increases with height. The above equations allow us to calculate M and N in non-standard atmospheres. We can then describe how an EM wave will bend, depending on the gradient of *N* (∂N/∂z), or gradient of *M* (∂M/∂z), shown by Figure 2, which describes that an EM wave will propagate parallel to the Earth's surface for ∂M/∂z = 0, away from the Earth's surface with ∂M/∂z > 0, and towards the Earth's surface with ∂M/∂z < 0. The corresponding relationships can be made with ∂N/∂z to describe the type of refraction also shown in Figure 2 (Turton et al. 1988).

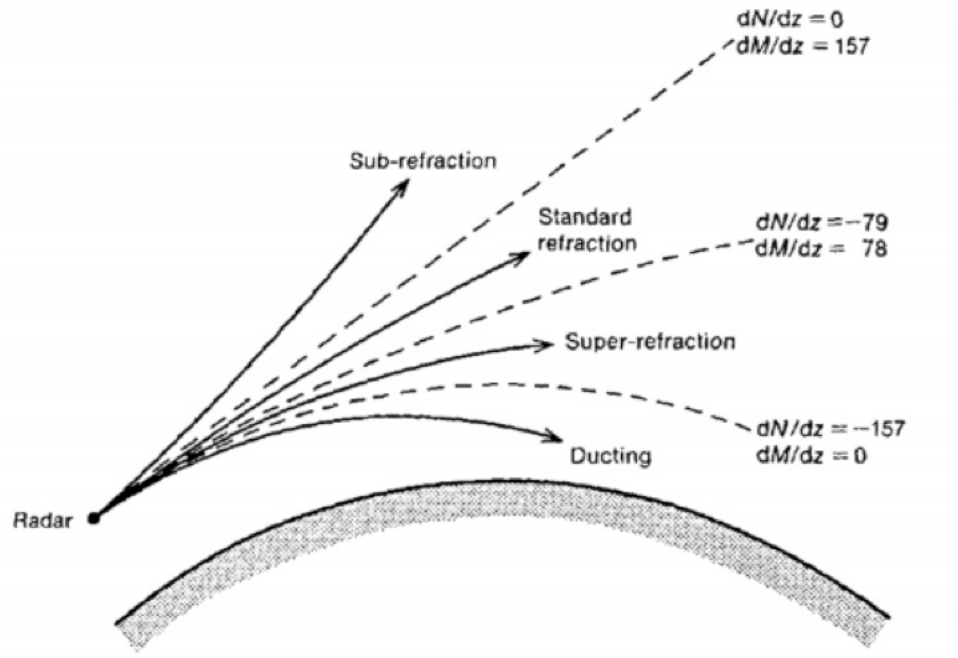
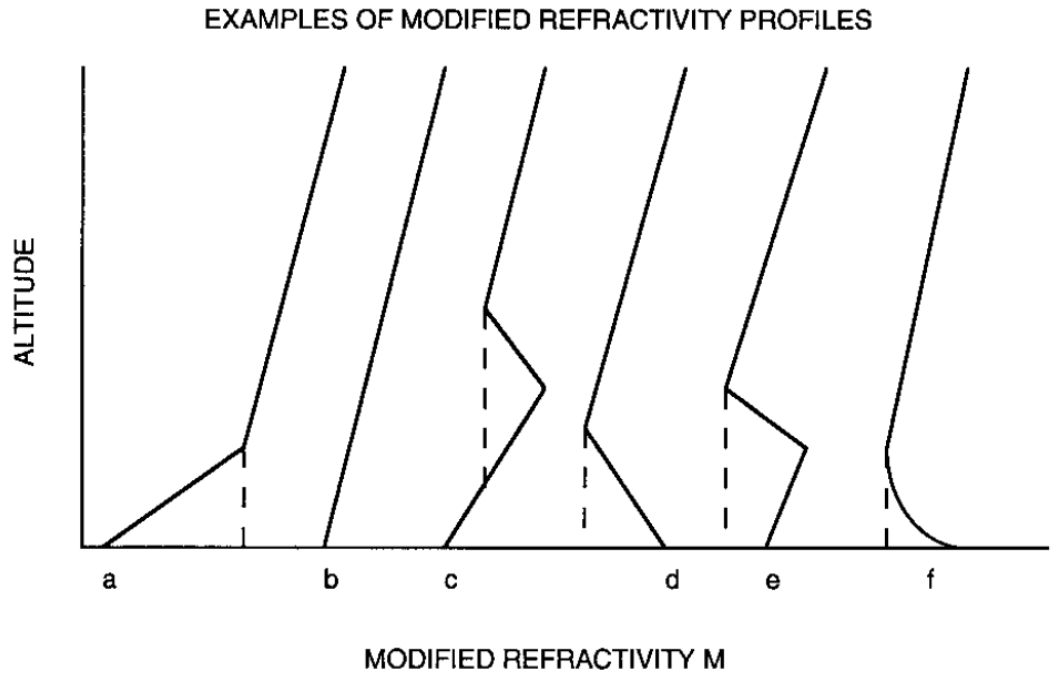


Figure 2. Categories of refractive propagation. Source: Turton et al. (1988).

Vertical gradient in water vapor throughout the air column is the dominant factor controlling the *M* gradient. Such *M* gradient results in different refractive conditions, some of which may be favorable for ducting to occur. (Babin et al. 1997). Figure 3 gives a few examples of the M profiles with the duct layer indicated when applicable.



"Plots of modified refractivity M versus altitude: (a) subrefractive layer denoted by dashed line; (b) normal refraction; (c) elevated duct denoted by dashed line; (d) surface duct denoted by dashed line; (e) surface duct (dashed line) due to elevated region of strongly negative vertical M gradient; (f) evaporation duct denoted by dashed line." In this figure from Babin et al. (1997).

Figure 3. Illustration of the Vertical Variation of Modified Refractivity, M in Different Ducting Conditions. The ducting layers are also indicated in each plot using a vertical dash line. Source: Babin et al. (1988).

The effects of the changing *M* with height on the propagation of a typical shipboard radar are illustrated in the bottom row of Figure 4 corresponding to the M-profiles in the top row. Trapping of the radar signals are clearly seen in subplots 2b and 5b in the presence of evaporation duct. The strong signal in the low levels in the surface duct and the skip zone in the surface-based duct are also illustrated in subplots 3b and 4b, which are in stark contrast with the propagation in the standard atmosphere (subplot 1).

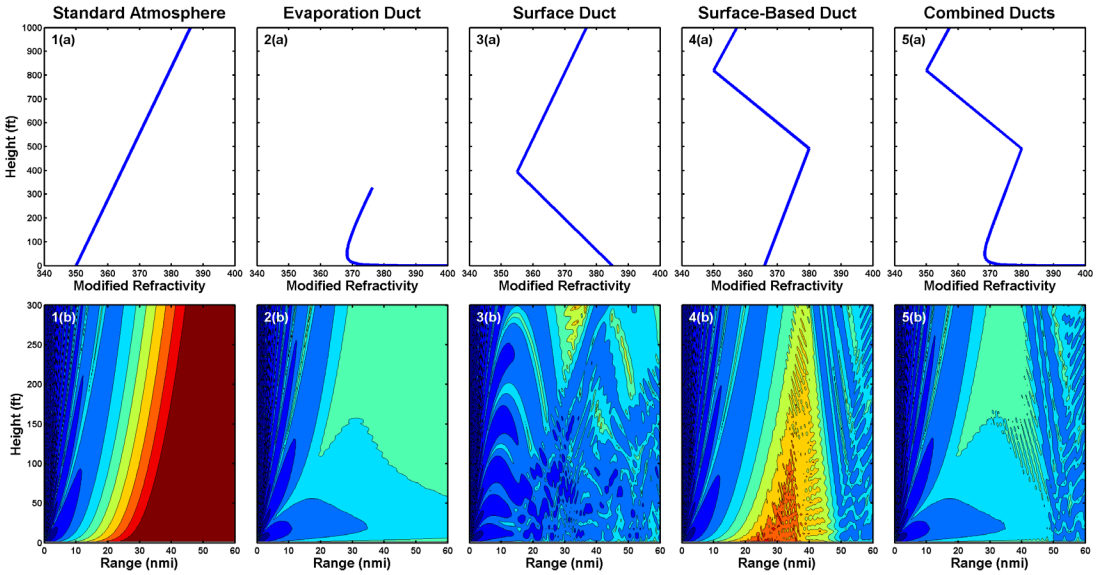


Figure 4. Propagation loss coverage diagram for a few ducting conditions shown in the top row. The propagation calculation was for a 6 GHz radar at typical shipboard height above the surface. Warm colors represent areas of higher propagation loss, cooler colors represent areas of lower propagation loss. Source: Frederickson (2014).

B. MODELING EVAPORATION DUCTS

As observed in the Figures 1–4, accurate forecast of EDH is crucial in determining realistic EM propagation to provide guidance to naval assets in detecting adversaries, or determining the standoff distance to decrease counter-detection. The U.S. Navy has developed models to provide such a capability, leading to the Navy Atmospheric Vertical Surface Layer Model (NAVSLaM, Frederickson 2014). Developed in the 1990s, NAVSLaM is based on Monin–Obukhov Similarity Theory (MOST). Although having some limitations in stable atmospheric conditions, it can provide reasonable results in open ocean unstable or near-neutral conditions. NAVSLaM can calculate the EDH utilizing environmental parameters from a wide range of sources such as NWP models (e,g, COAMPS), climatological databases, and in-situ observations (Frederickson 2014). Since NAVSLaM only provides the M-profiles in the atmospheric surface layer, its profiles need to be merged with corresponding profiles in the atmosphere above to yield a complete profile of the full air column to be used as input to propagation models such as the advanced propagation model (APM).

In Figure 5, we can see a conceptual TDA process, and the steps where NWP model predictions are utilized in order to characterize the EDH through the NAVSLsM evaporation duct model. The last step is to generate an EM signal propagation plot by utilizing a propagation model. The propagation model in this illustration is the APM model.

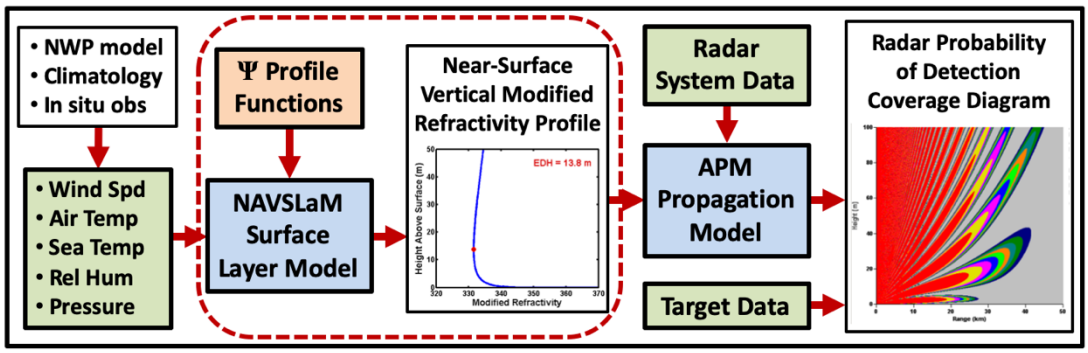


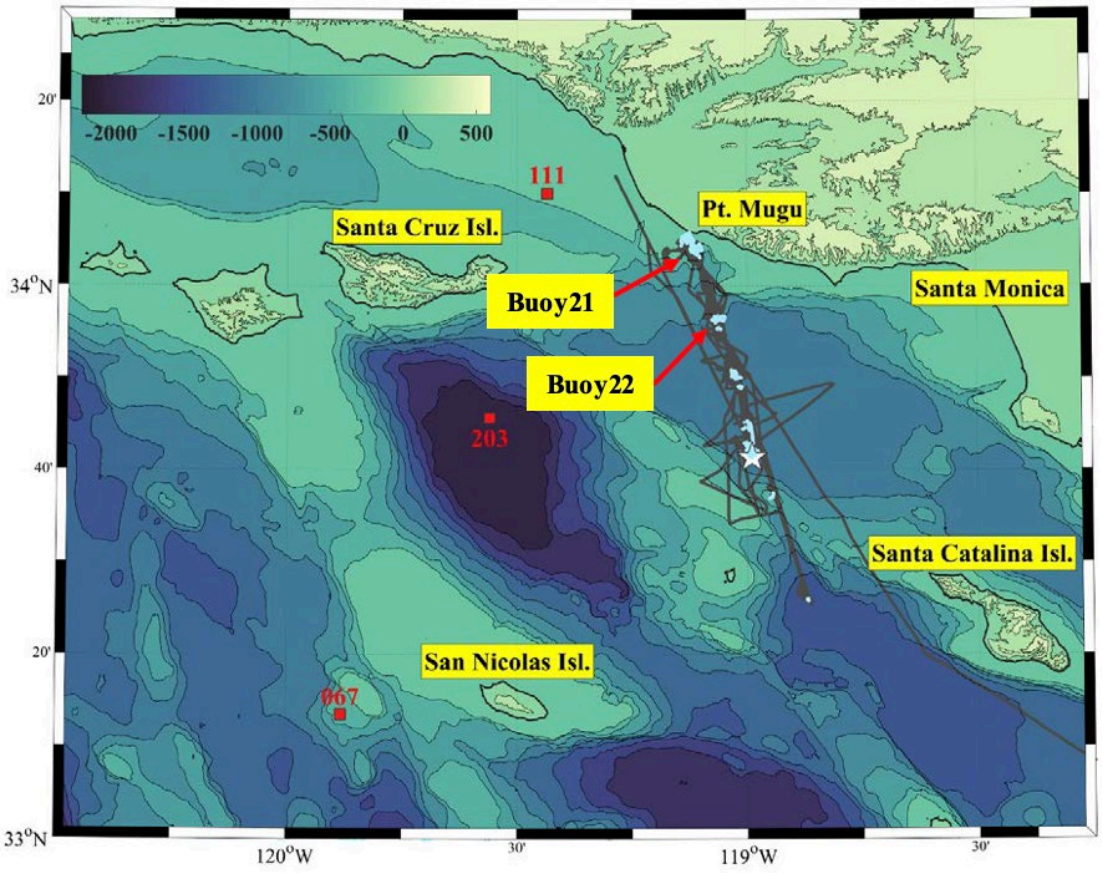
Figure 5. How NAVSLaM fits into the radar performance prediction process. Source: Frederickson (2014).

C. CASPER-WEST SYNOPSIS

The Coupled Air-Sea Processes and Electromagnetic ducting Research (CASPER) is an Office of Naval Research (ONR) funded research project which focuses on the effects of marine atmospheric boundary layer (MABL) on EM energy propagation. CASPER field study focused on air-sea interaction and boundary layer processes that shape the M-profiles in the lower 1-km of the atmosphere that impact RF propagation (Wang et al. 2018). The project relied heavily on measurements and analyses of the atmospheric factors that contribute to the modified index of refraction (M): ambient temperature, surface pressure, sea surface temperature, wind, and vapor pressure. Based on these measurements, the MOST-based evaporation duct models are evaluated, since the theory provides a foundation for calculating the vertical gradients for temperature, vapor pressure, and wind, to determine the near-surface refractivity profile, which in turn can be used as an input to determine the probability of radar detection or other TDAs (Ortiz-Suslow et al. 2019).

CASPER-West was conducted from September to October, 2017 in the waters of Southern California, within the Santa Monica Basin (Figure 6). The main platforms of the field study were the research platform Floating Instrument Platform (R/P FLIP), Research Vessel Sally Ride (RVSR), along with a workboat on RVSR. Also involved in CASPER-West was a land-based EM and meteorological station at the Pt. Mugu Sea Range, a Twin Otter research aircraft with a controlled towed vehicle (CTV), three surface buoys, and five surface Wave Gliders (Wang et al. 2018). During CASPER-West, there was also a designated path between the shore site and the location of the FLIP for EM propagation measurements. FLIP was an invaluable asset since it was outfitted with multiple sampling capabilities such as rawinsondes, high-rate sampling instruments at multiple levels on a vertical mast, and other in situ and remote sensing instruments to sample throughout the lower troposphere. Figures 6–9 provide a good visual summary the setup of R/P FLIP in CASPER-West (Ortiz-Suslow et al. 2019). Similar sensors and measurements were made on RVSR, but with less vertical levels due to physical space limitations. Wave Gliders and other autonomous vehicles were also deployed from RVSR to obtain measurements closer to the sea surface. An instrumented workboat was used to sample the near-surface profiles using tethered balloon based sensors (Figure 10). Multiple levels of the ABL were sampled by the Twin Otter with the CTV along a pre-planned sampling pattern in the experiment area. Lastly, two instrumented buoys were placed between the shore and FLIP to further measure mean atmospheric temperature, humidity, wind speed and direction, and surface water temperature. CASPER-West obtained and extensive dataset to characterize the upper atmosphere and the MABL over the experiment operating area (Wang et al. 2019).

For much of CASPER-West, the atmospheric conditions remained with calm winds, characteristic of southern California bight in early autumn season. However, typical for the region as well, several Santa Ana events, which are warm and dry offshore flow, provide some of the extreme conditions during the experiment (Ortiz-Suslow et al. 2019).



Buoy 21 and Buoy22 locations added.

Figure 6. CASPER-West study site marking the location of FLIP (white star), the track line of the R/V Sally Ride (gray), and the locations of the small boat operations (light blue). Red squares mark nearby NDBC/CIP buoys. Topography relative to sea level is given in meters. Source: Ortiz-Suslow et al. (2019).

Figure 7. FLIP during the CASPER-West experiment with several features highlighted. Note that the heading of FLIP is the direction the keel points (x). The platform coordinate system is also given. Photo credit: D. Khelif, University of California at Irvine. Source: Ortiz-Suslow et al. (2019).

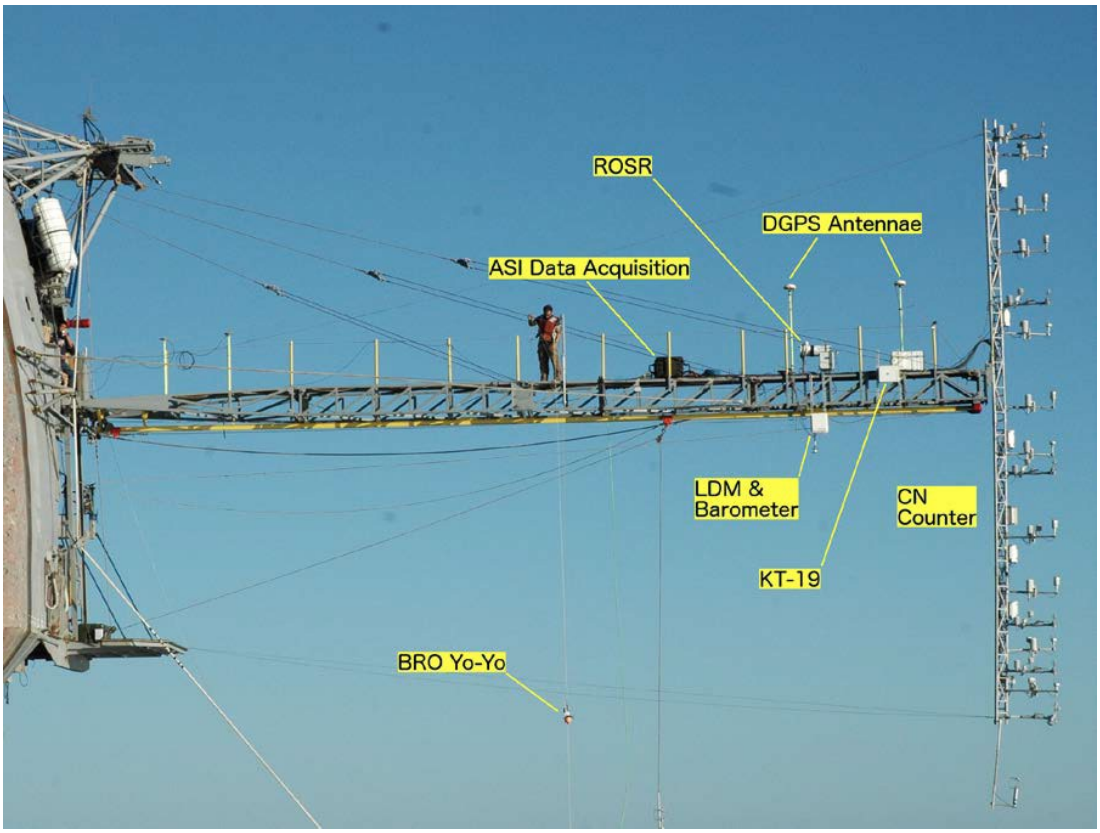


Figure 8. A view of FLIP port boom with additional NPS measurement systems highlighted. Source: Ortiz-Suslow et al. (2019).

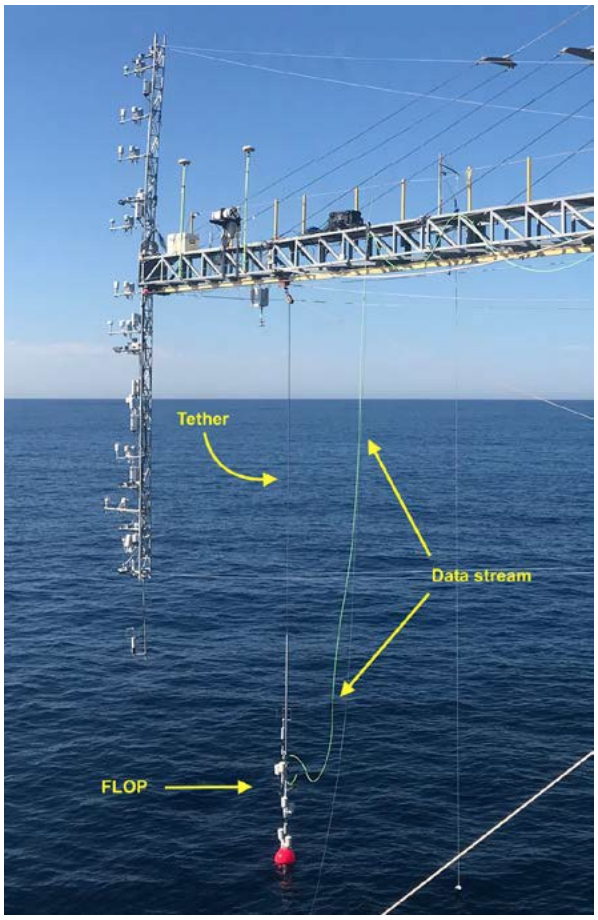


Figure 9. FLIP's Lowest Observing Platform (FLOP) tethered to FLIP port boom during CASPER-West. Image taken October 16, 2017, 10:30 PDT. Source: Ortiz-Suslow et al. (2019).

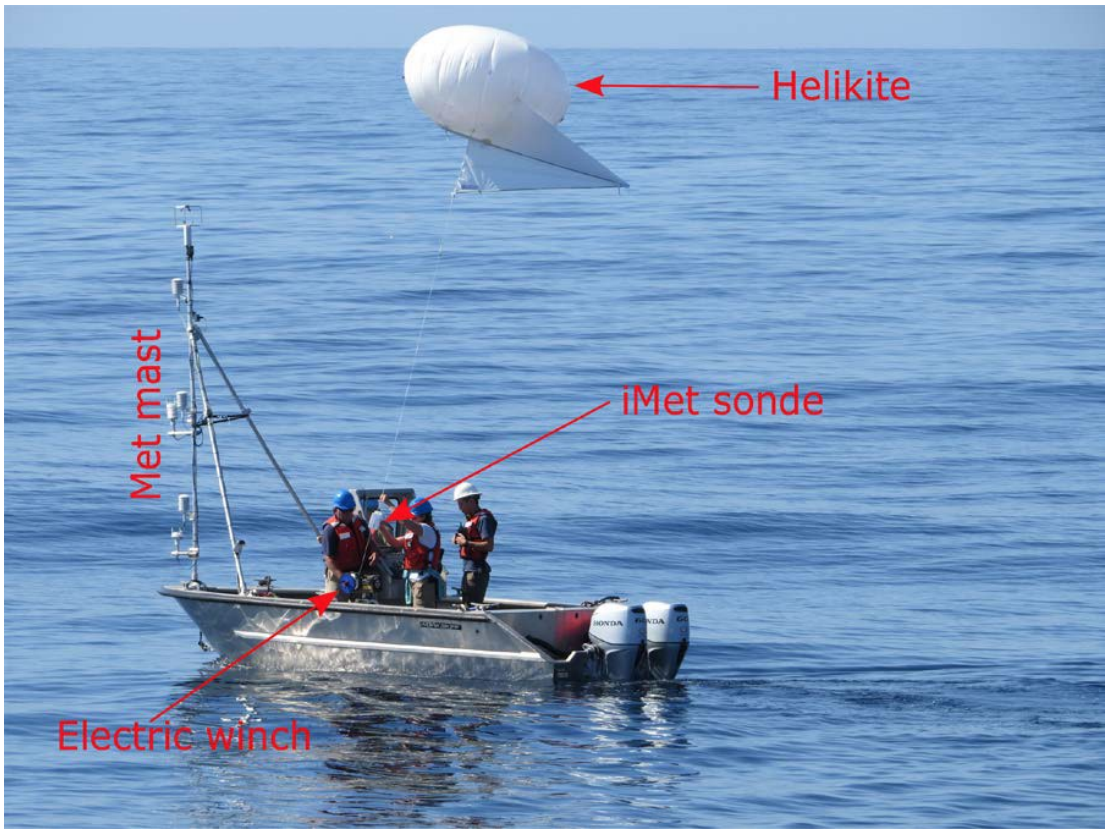


Figure 10. Components used in the air-sea interaction sampling from the R/V Sally Ride small boat. Source: Ortiz-Suslow et al. (2019).

III. METHODOLOGY AND DATASET OVERVIEW

A. STEPS IN THE AI/ML TECHNIQUES

Most data scientists agree that when applying any ML algorithm, the next general five steps must be considered (Brownlee 2019):

1. Define the problem

   Here is where we ask the questions of what the problem is, why it needs to be solved, how could the problem be solved, along with any assumptions, constraints, and benefits of solving the problem.

2. Prepare the data

   This step will provide information about the data distribution, missing data points, histograms, any data relationships, and correlations. In this step the data is also cleaned up by taking care of any missing data points, or where the instrument algorithm due to error or some other cause has inserted a marker such as not-a-number (NaN), -99, -999, as well as identifying outliers. The data is divided into training, testing, and validation sets. If needed, any preprocessing, transformation, or normalization is applied. This step is more commonly known as Feature Engineering.

3. Evaluate the algorithm

   Metrics are used to rate the algorithm results. Considerations are given to accepted statistical parameters to measure the effectiveness of one model over another.

4. Improve the results

   Several available extra options are considered depending on the algorithm package used, since not all packages include or work well with improved options, i.e., bagging, boosting, or blending of data as part of data preparation prior to evaluating the algorithm once again. Careful consideration should be given to the improvement options, since not all of the options work well every time.

5. Present the results.

   Graphics are generated to explain the answers given by a particular model, any model limitations and findings are provided, and the final step is to deploy the model into an operational environment, in a way, ready for production and into real world conditions.

B. FEATURE ENGINEERING AND THE CASPER-WEST DATA

The process known as feature engineering is the most time-consuming portion of solving a problem via ML approach, since it scrutinizes the data used for modeling. This data has to be analyzed, and at times filtered to find out which are the more appropriate features which affect the predictions. This process is vital to the success of predictive modeling. The primary goal is to reduce modeling error for the predictive target; however, there is no explicit process that fits all situations, and therefore, it requires human involvement and intuition, knowledge of the data, and a good representation of how the features affect the prediction (Khurana et al. 2018).

In this case, we had to find outliers, decide how to represent missing data, not-a-number (NaN) or -999 which represented missing or not measured data points.

For EDH calculations, the features affecting the predictions are ambient air temperature, sea surface temperature, atmospheric pressure, relative humidity, and wind speed (Bean and Dutton 1968). The data explored in this thesis is from Buoy 21 and Buoy 22 (Figure 6).

Figure 11 shows the time series plots of all variables measured on Buoy 21. We found that the top water temperature had multiple outlier values given at 0 ºC, which were not reasonable values during late summer or early autumn in Southern California. These 'bad data points' were removed, and replaced with NaN, so that later on when a linear interpolation was used, or some other ML algorithm was applied, the non-physical values did not have an outsized effect in training or testing the predictive model.

We noticed meteorologically expected patterns of changes between air temperature, and relative humidity. For example, in the absence of any major wind direction or air mass changes, relative humidity typically decreased as air temperature increased. This pattern can be changed or enhanced by events like Santa Ana winds, bringing warm dry air from overland California into our study area. The statistical information from Python pandas dataframe for CASPER-West Buoy 21 are displayed on Table 1.

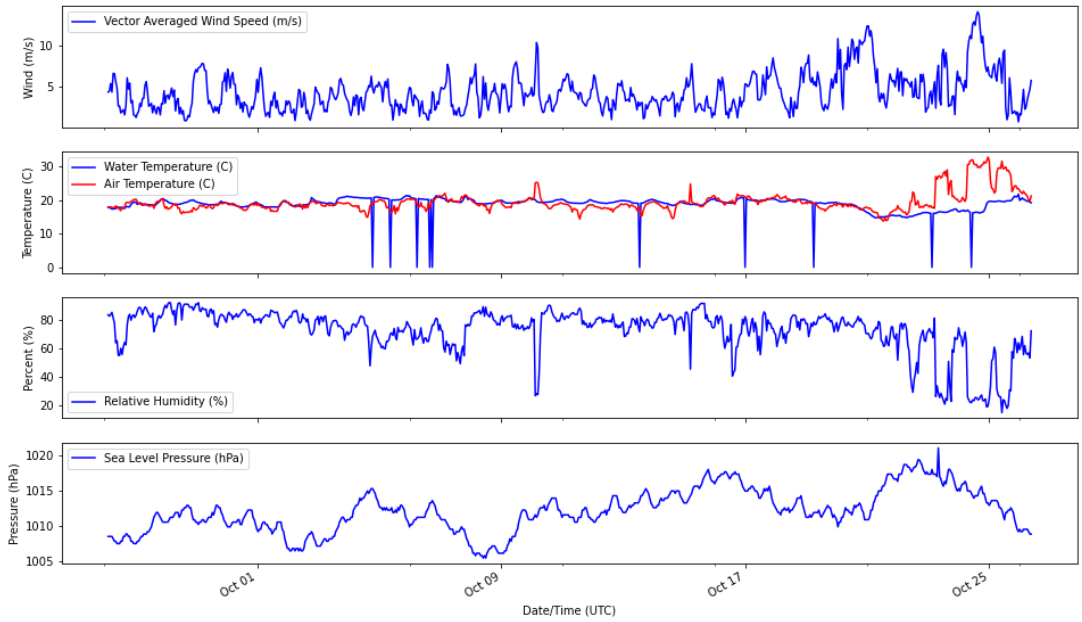


Figure 11. CASPER-West Buoy 21 – Average Wind Speed, Water Temperature, Air Temperature, Relative Humidity, and Sea Level Pressure plots.

Table 1. CASPER-West Buoy 21 statistics.

	Air Temperature (C)	Water Temperature (C)	Relative Humidity (%)	Sea Level Pressure (hPa)	Vector Averaged Wind Speed (m/s)	u (m/s)	v (m/s)
count	730.000000	730.000000	730.000000	730.000000	730.000000	730.000000	730.000000
mean	19.441233	18.784192	73.016575	1012.098137	4.351985	1.690377	-1.146275
std	2.971781	2.628204	15.705696	2.996372	2.357772	2.683525	3.625809
min	13.800000	0.000000	14.700000	1005.440000	0.740799	-5.660415	-12.234693
25%	17.900000	18.630000	68.900000	1010.520000	2.651959	-0.350722	-3.586301
50%	18.900000	19.280000	77.550000	1011.880000	3.832608	2.031813	-1.301951
75%	19.900000	19.957500	82.700000	1013.910000	5.584290	3.630622	0.718617
max	32.900000	21.820000	92.700000	1021.020000	14.183221	9.486748	10.572847

The distribution of the features was examined so that we might detect any outliers which would affect the regression models. Figure 12 shows the distribution of all the key variables, and we observed that in our buoy datasets surface water temperature was recorded approximately 5% of the time to have values at 0 ºC. This is non-physical with the ocean around Santa Barbara in the Fall, these data were removed as bad data. We also

observed significant deviations from the ‘normal’ data variability, such as at the end of the field campaign around 25 Oct 2017. However, the observed warm air temperatures with corresponding low humidity were physically reasonable as they occurred in the last five days during a strong Santa Ana wind event.

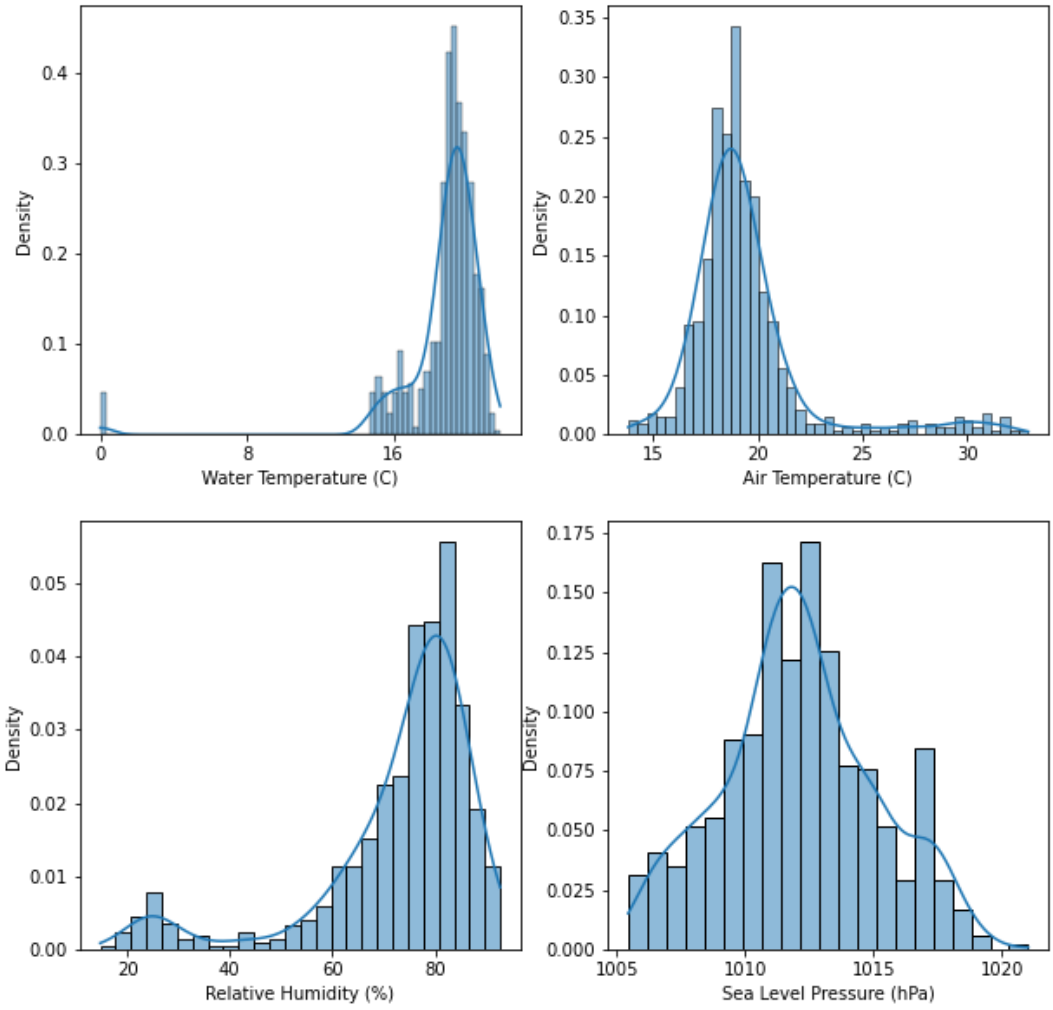


Figure 12. CASPER-West Buoy 21 – Water Temperature, Air Temperature, Relative Humidity, and Sea Level Pressure histograms. The vertical axis label ‘Density’ refers to the empirical probability distribution density.

After removing the unreasonable data values (outliers) and interpolating the water temperature values, the data was plotted to ensure there were not any artificial biases or if newer significant outliers were now evident (Figure 13).

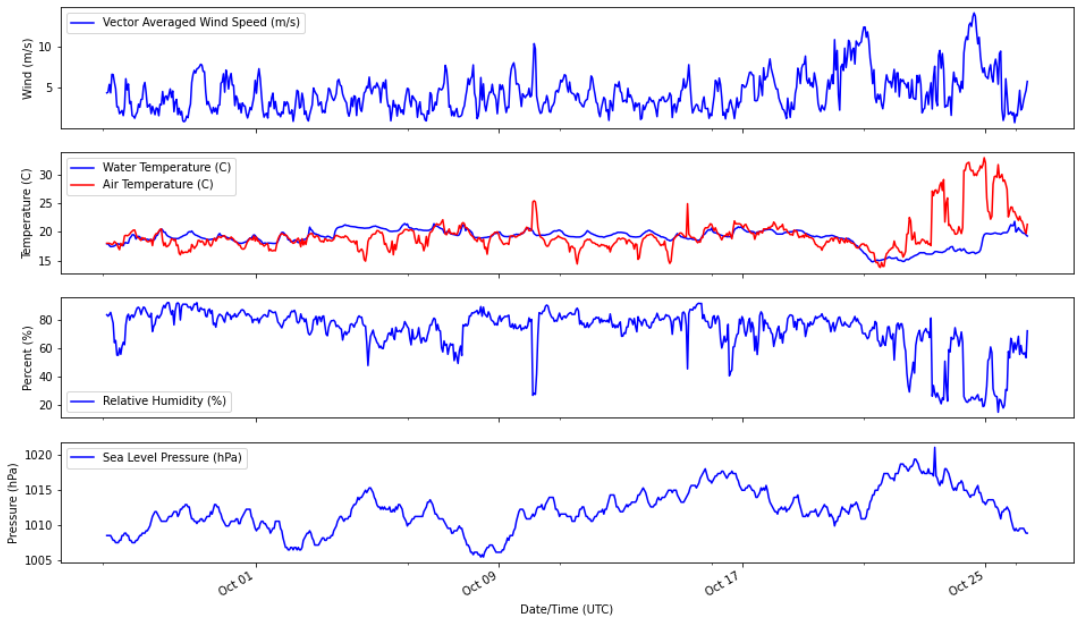


Figure 13. CASPER-West Buoy 21 – Average Wind Speed, Water Temperature, Air Temperature, Relative Humidity, and Sea Level Pressure plots – Modified data.

Statistical information from modified data for CASPER-West Buoy 21 is displayed in Table 2. The descriptive statistics were obtained utilizing the pandas dataframe describe() function, which included a summary of the central tendency, the distribution of the dataset, excluding all NaNs.

Table 2. CASPER-West Buoy 21 statistics – Modified data.

	Air Temperature (C)	Water Temperature (C)	Relative Humidity (%)	Sea Level Pressure (hPa)	Vector Averaged Wind Speed (m/s)	u (m/s)	v (m/s)
count	730.000000	730.000000	730.000000	730.000000	730.000000	730.000000	730.000000
mean	19.441233	19.049493	73.016575	1012.098137	4.351985	1.690377	-1.146275
std	2.971781	1.427872	15.705696	2.996372	2.357772	2.683525	3.625809
min	13.800000	14.770000	14.700000	1005.440000	0.740799	-5.660415	-12.234693
25%	17.900000	18.662500	68.900000	1010.520000	2.651959	-0.350722	-3.586301
50%	18.900000	19.310000	77.550000	1011.880000	3.832608	2.031813	-1.301951
75%	19.900000	19.990000	82.700000	1013.910000	5.584290	3.630622	0.718617
max	32.900000	21.820000	92.700000	1021.020000	14.183221	9.486748	10.572847

The histograms of the modified data were generated and presented in Figure 14. Some of the extreme values are observed in this figure, but they can be explained with the environmental conditions, especially during the Santa Ana event which presented with warmer air temperatures, lower humidity percentages, and cooler water temperatures (possibly due to a stronger upwelling generated by stronger offshore winds) (Figure 14). The plots were generated utilizing the Python seaborn histplot() function, where the bins were automatically generated utilizing the default bin size based on the sample size and variance. A separate selection was the density option, which normalized the counts so that the area of the histogram is 1, also, the kernel density estimate option was selected so that it presented a smooth distribution plot shown as a continuous line.

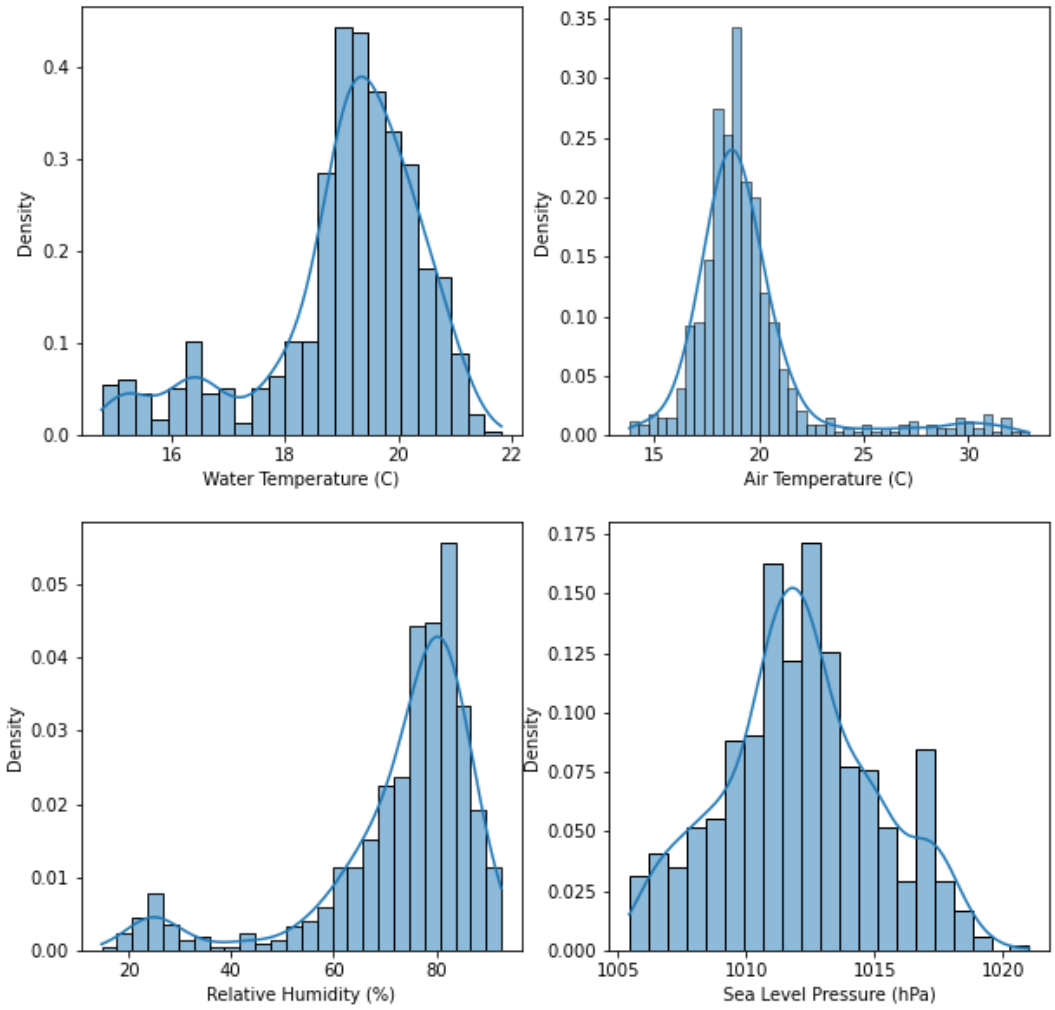


Figure 14. CASPER-West Buoy 21 – Water Temperature, Air Temperature, Relative Humidity, and Sea Level Pressure histograms– Modified data. The vertical axis label 'Density' refers to the empirical probability distribution density.

The Figure 15 shows the distribution of winds over the sampling period. The Average Winds Speed and Direction were converted to wind vectors *u* and *v* via:

$$u = -ws * sin(\theta)$$

$$v = -ws * cos(\theta)$$

$$\theta = \frac{360^o}{c} * atan2(v, u) + 180^o$$

where *ws* is the wind speed (m s^{-1}), and θ is the meteorological wind direction (deg) as measured by an instrument, C =360º or 2π. (Stull 2017). The wind 2D histograms were generated via the Python matplotlib.pyplot hist2d() function. The bins for all such plots were set at 10.

For CASPER-West Buoy 21, note the general prevalence of westerly winds (i.e., positive u wind, and small values of v wind, evident by the yellow histogram box).

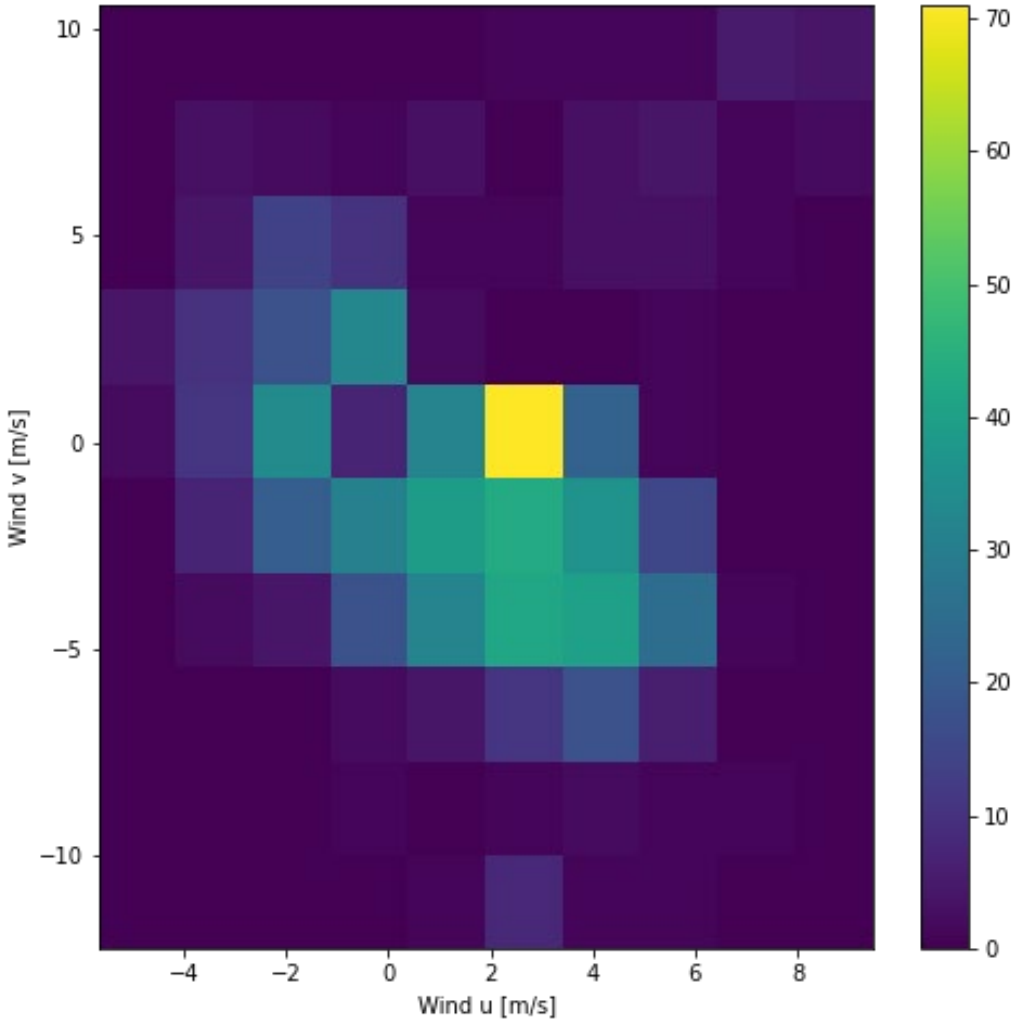


Figure 15. CASPER-West Buoy 21 calculated wind vectors 2D histogram (colorbar/values indicate number of hourly readings in the given u-v wind range).

The Pearson correlation coefficient is a measure of how two features are related to each other, it ranges between 1 and -1, with the highest correlation being closer to 1 or -1, and the lowest correlation being closer to 0. In this case, we observed a strong negative correlation between air temperature and relative humidity. That is, as air temperature increases, relative humidity decreases, and vice versa. Air temperature and water temperature showed the lowest correlation in this dataset.

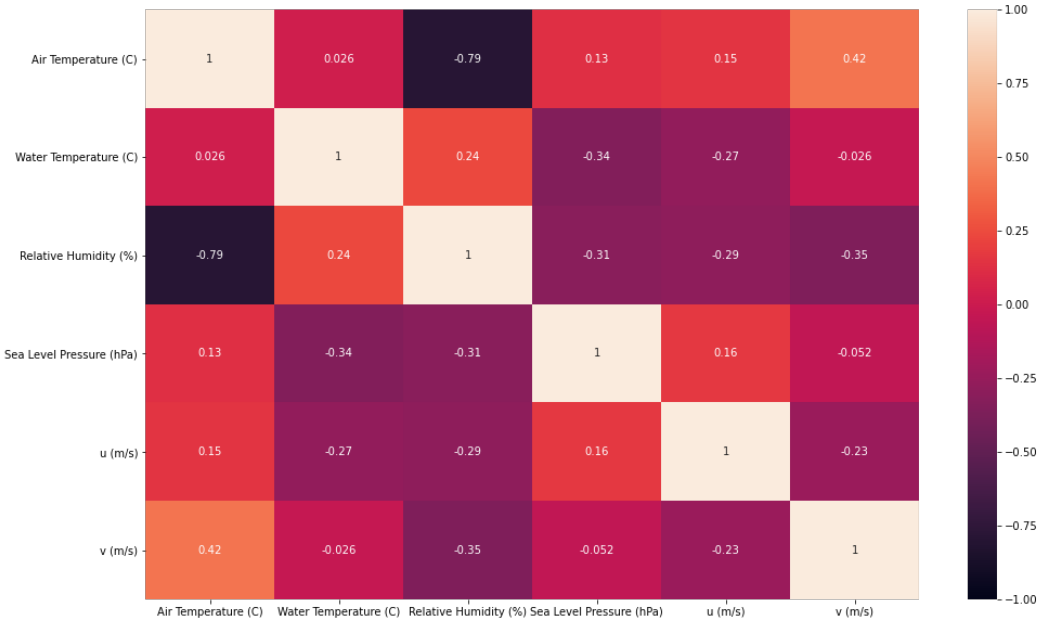


Figure 16. CASPER-West Buoy 21 Pearson correlation coefficient – Modified data.

Similarly, for Buoy 22, we employed similar feature engineering process for the data, since the sampling rate was every 15 minutes vice every hour, also, shown on Figures 17–22, the data had similar issues with the near-surface water temperature as in Buoy 21 with measurements of 0 ºC. In addition to removing these data points, the entire dataset was interpolated to provide hourly samples, so that the two buoy cases would be representative of similar conditions. Coding was done to examine the 15-minute data separately, but results were not examined in depth due to time limitations.

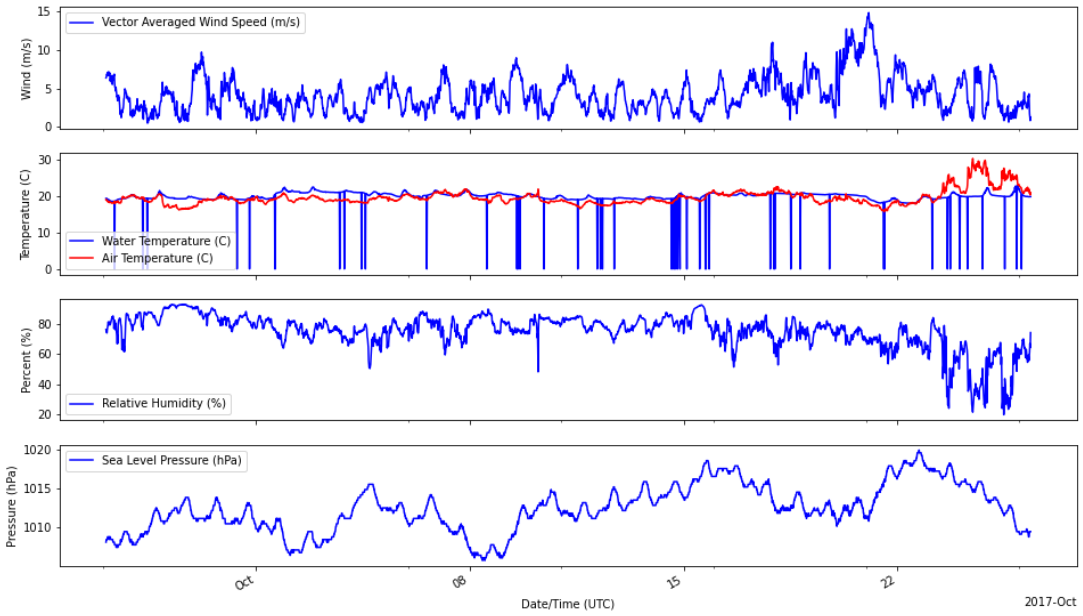


Figure 17. CASPER-West Buoy 22 – Water Temperature, Air Temperature, Relative Humidity, and Sea Level Pressure plots – Original data at 15-minute data interval.

Table 3. CASPER-West Buoy 22 statistics.

	Air Temperature (C)	Water Temperature (C)	Relative Humidity (%)	Sea Level Pressure (hPa)	Vector Averaged Wind Speed (m/s)	u (m/s)	v (m/s)
count	2779.000000	2779.000000	2779.000000	2779.000000	2779.000000	2779.000000	2779.000000
mean	19.569737	19.653454	75.187154	1012.453113	4.140352	1.437556	-1.664076
std	1.989047	2.776949	11.468611	2.987853	2.349869	2.495879	3.406420
min	15.700000	0.000000	20.000000	1005.780000	0.509300	-6.133835	-13.332760
25%	18.400000	19.350000	71.000000	1010.520000	2.412742	-0.546129	-3.947420
50%	19.200000	20.000000	77.300000	1012.220000	3.750297	1.215878	-2.129845
75%	20.200000	20.560000	82.200000	1014.250000	5.445390	3.305849	0.704509
max	30.300000	22.870000	92.900000	1020.010000	14.790265	8.272065	8.872900

From the histograms, we can further corroborate the issues with water temperature data, since approximately 10% of the data points were outliers that needed to be removed. (Figure 18)

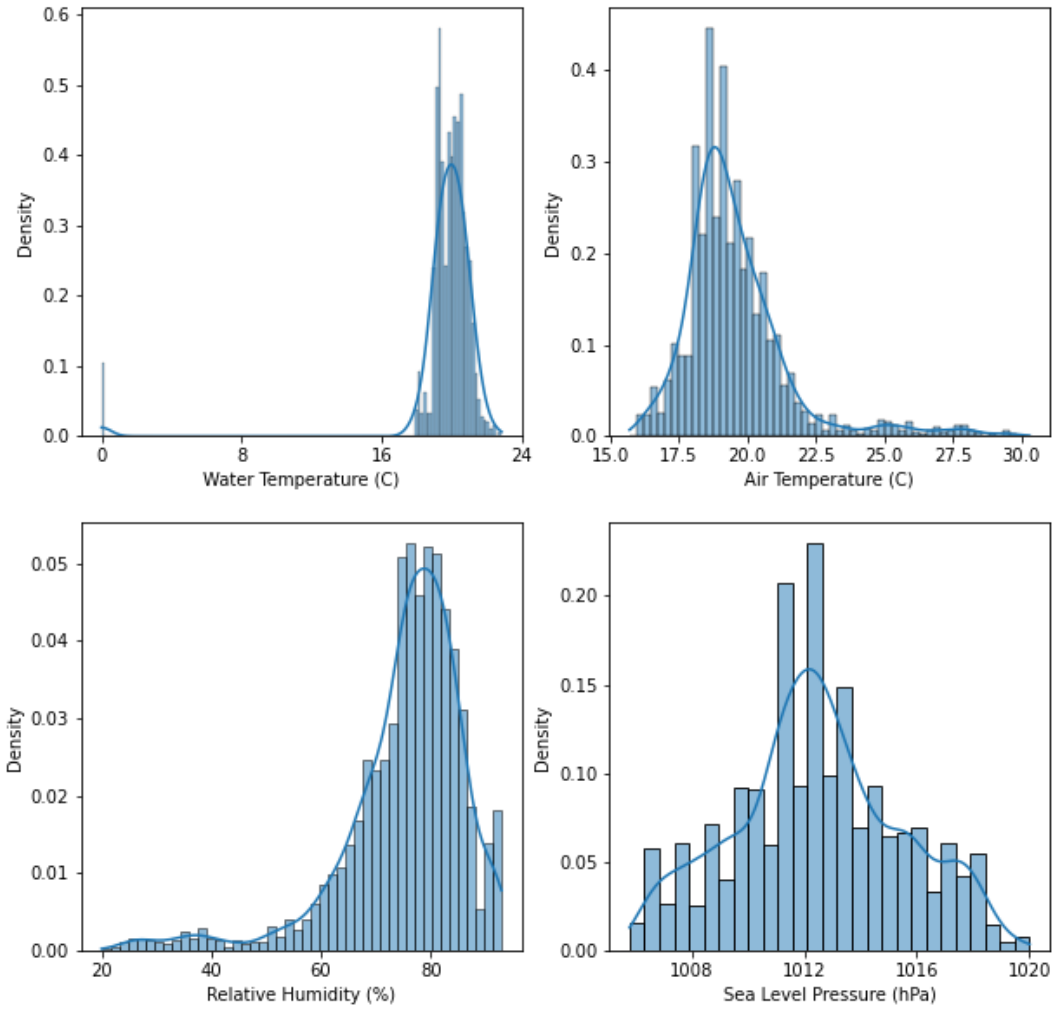


Figure 18. CASPER-West Buoy 22 – Water Temperature, Air Temperature, Relative Humidity, and Sea Level Pressure histograms – Original data at 15-minute data interval. The vertical axis label 'Density' refers to the empirical probability distribution density.

After the water temperature outliers were removed, and the dataset was interpolated to hourly intervals, shown in Figure 19 and Table 4 showed the modified data.

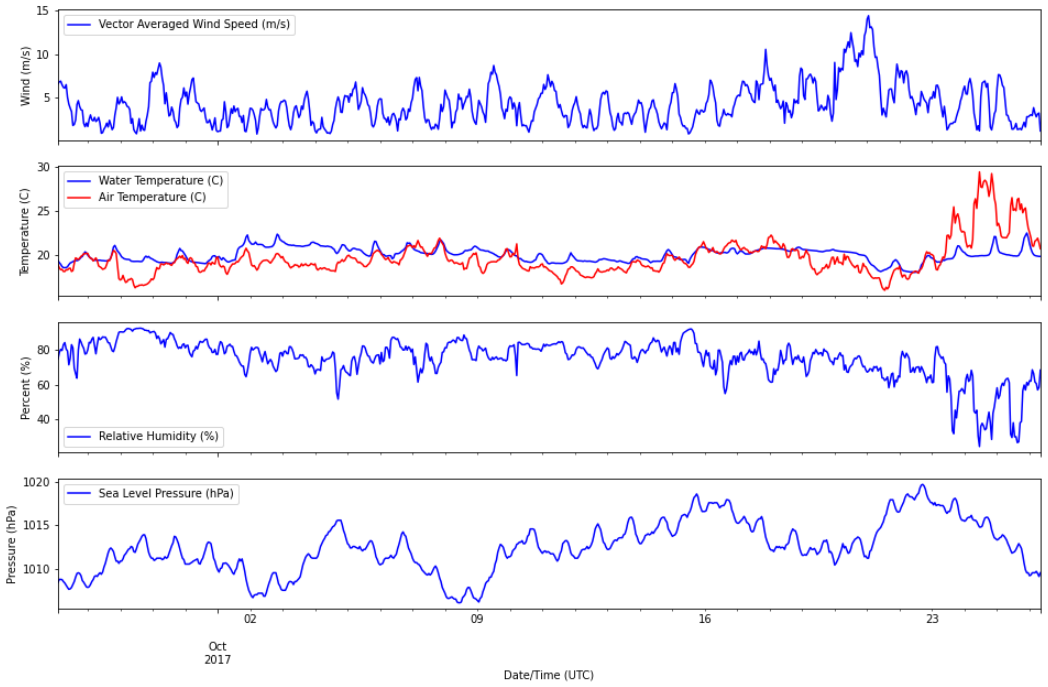


Figure 19. CASPER-West Buoy 21 – Water Temperature, Air Temperature, Relative Humidity, and Sea Level Pressure plots – Modified data.

Table 4. CASPER-West Buoy 22 statistics – Modified data.

	Air Temperature (C)	Water Temperature (C)	Relative Humidity (%)	Sea Level Pressure (hPa)	Vector Averaged Wind Speed (m/s)	u (m/s)	v (m/s)
count	727.000000	727.000000	727.000000	727.000000	727.000000	727.000000	727.000000
mean	19.584814	20.009311	75.045633	1012.495625	4.156069	1.450313	-1.673630
std	1.998959	0.798648	11.373821	2.993425	2.316907	2.446218	3.384186
min	15.950000	17.997500	24.200000	1006.035000	0.779383	-5.678196	-13.073827
25%	18.441667	19.368750	70.637500	1010.673000	2.403097	-0.491051	-3.978597
50%	19.166667	20.017500	77.100000	1012.333333	3.749011	1.240453	-2.121090
75%	20.225000	20.556250	82.012500	1014.457500	5.335642	3.292281	0.678847
max	29.466667	22.490000	92.775000	1019.755000	14.445588	7.601716	8.661188

The modified histograms are displayed in Figure 20 below, displaying significant less outliers, and a better distributed dataset.

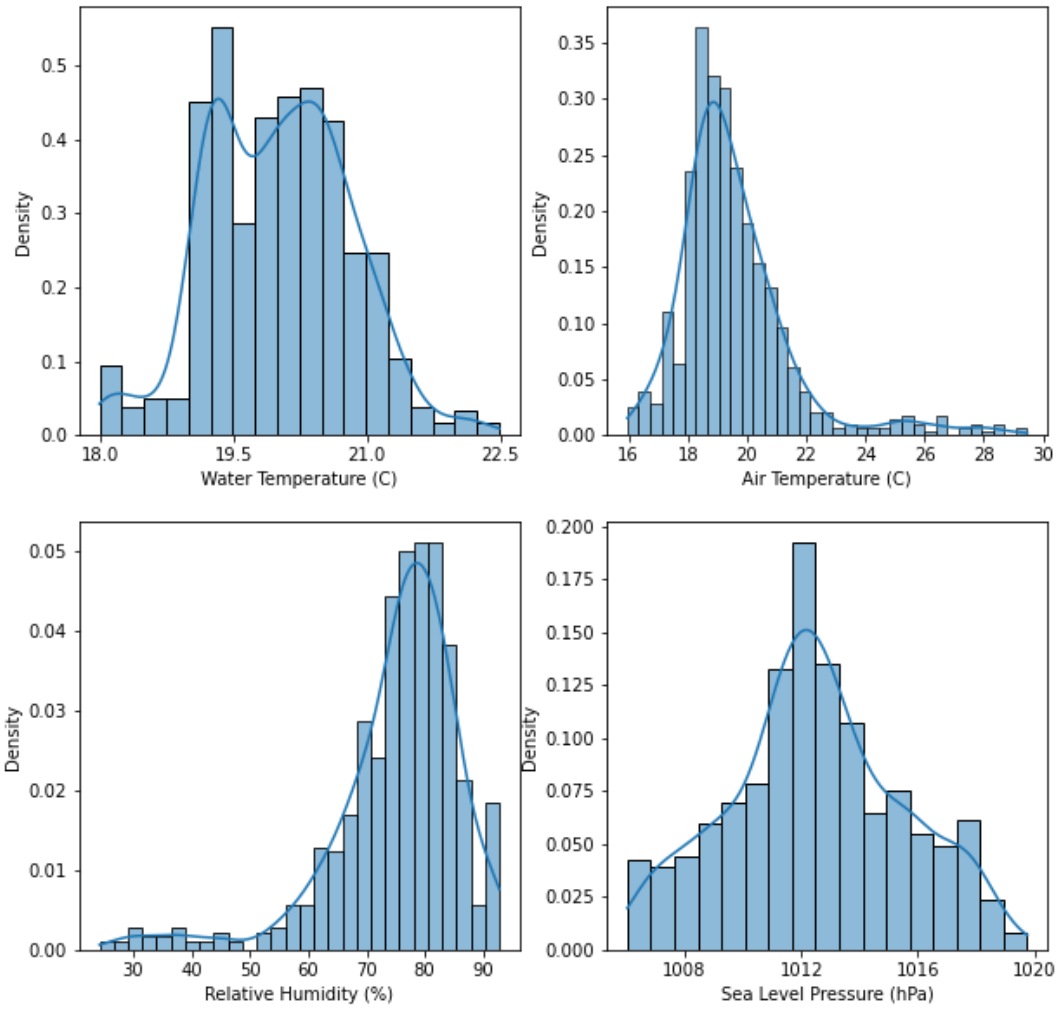


Figure 20. CASPER-West Buoy 22 – Water Temperature, Air Temperature, Relative Humidity, and Sea Level Pressure histograms – Modified data. The vertical axis label 'Density' refers to the empirical probability distribution density.

After the outlier removal and hourly interpolation for Buoy 22 dataset, we observed that the distribution was similar to the original data. Figure 21 with the interpolated data also showed similar representative distribution (i.e., a general prevalence of northwesterly winds with an additional prevalence of southeasterly winds), which provided confidence in the interpolation process.

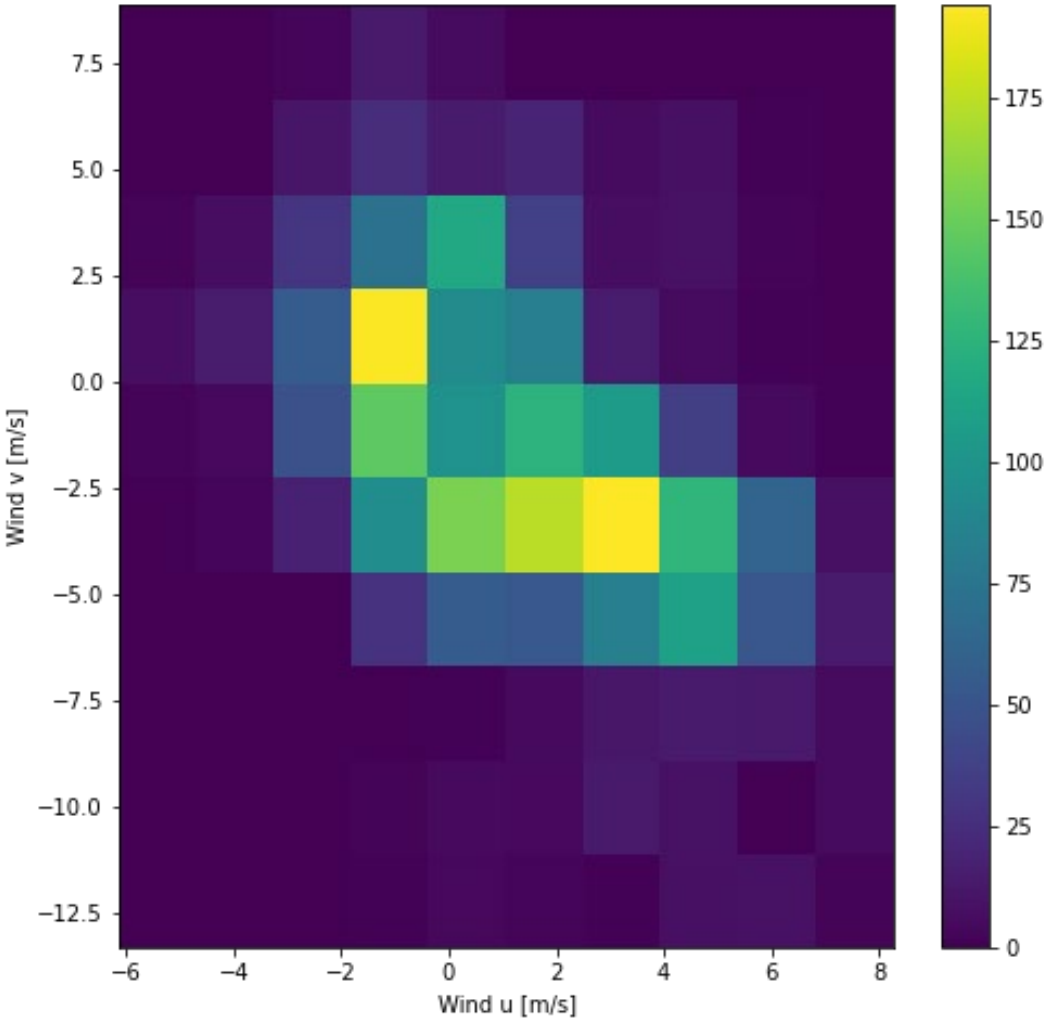


Figure 21. CASPER-West Buoy 22 calculated wind vectors 2D histogram. (colorbar/values indicate number of 15-minute readings in the given u-v wind range).

After the Buoy 22 data was averaged hourly, the 2D histogram for the wind vectors was affected by the reduction on the predominantly northwesterly winds, and now more northerly winds instead. The southeasterly prevalence remained. (Figure 22)

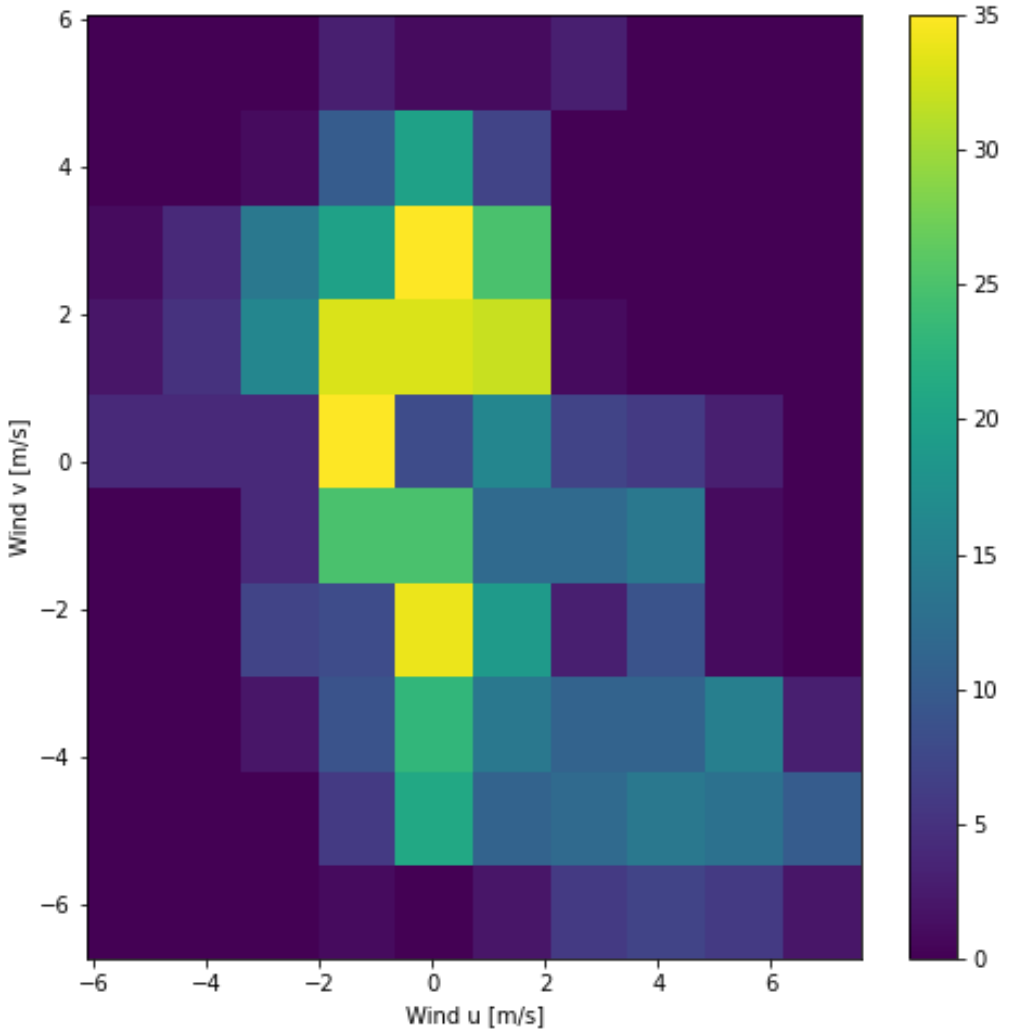


Figure 22. CASPER-West Buoy 22 calculated wind vectors 2D histogram – Modified data (colorbar/values indicate number of hourly readings in the given u-v wind range).

The dataset was broken down into three separate periods to evaluate ML algorithms, shown in Figure 23. The periods were chosen based on early tests of the algorithms after it was noticed that early in the data time series we saw predominantly diurnal changes (Case 1), followed by a pronounced change in conditions (Case 2), which lead to a Santa Ana event during lasting approximately five days (Case 3). This presented interesting and challenging variability in conditions for each of the algorithms to attempt to predict, potentially illustrating the best and worst cases of the ML approach.

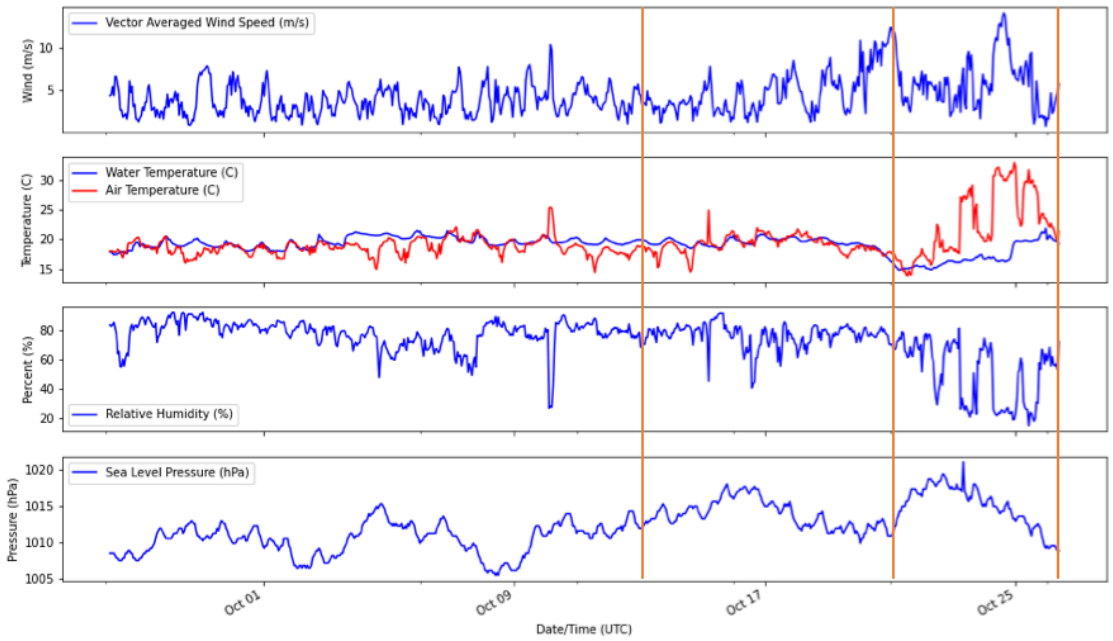


Figure 23. CASPER-West Buoy 21 – Water Temperature, Air Temperature, Relative Humidity, and Sea Level Pressure plots – Modified data. The vertical orange lines separate the data into three sections to be referred to as Case1, Case2, and Case3.

C. AI TECHNIQUE APPLIED TO EDH PREDICTION

The programming language Python was chosen because it is a high-level language, widely available, open source, graphical user interface (GUI) compatible, and object-oriented capable (https://www.python.org). Also, Python version 3.6.8 was chosen since it was available in the DOD approved programming languages. There are several modeling packages that have been developed for Python. Two used were: Scikit-learn (version 0.24.2) and TensorFlow (version 2.0.0). Scikit-learn's linear regression (LR), decision tree (DT) and random forest (RF) regressors were utilized for modeling, training, testing, and forecasting the individual features to input into NAVSLaM to calculate EDH/EDS, and to separately forecast EDH/EDS directly. In a similar approach, a TensorFlow regressor was explored.

For each case, the buoy data was split into 80% for training, and 20% for testing. The up to 6-hr forecasts were validated with the buoy observations.

The predictive algorithms were used in a supervised data analysis manner. That is, observations were correlated with known EDH/EDS (as calculated from NAVSLaM). Supervised learning in general is a method in which the historical data is employed to train and test the predictive classification or regression algorithms to predict future outcomes, and in this case a forecast for EDH/EDS, and EDH features (Kuhn and Johnson 2020). In most cases, data transformation via scaling factors, or normalization is also needed prior to introducing it to an algorithm, since not all algorithms would benefit by the transformation process, this portion of feature engineering is based on trial and error, for which some knowledge of the data is needed (Khurana et al. 2018). For this reason, data transformation was applied to all the considered algorithms.

Multiple options were considered for this project. Ultimately, we decided to run the algorithms with and without data transformation or scaling, and algorithm runs utilizing current and one, two and three hours prior for all the features (*x(t), x(t-1), x(t-2), x(t-3)*).

Computational run time for all approaches was calculated utilizing Python functions to demonstrate the feasibility of shipboard use, and show that this process would not be hindered by considerable wall-clock time, which would have rendered this approach less valuable to the framing process of calculating EDH/EDS, and EM propagation. (Appendix G)

D. POST-PREDICTION ANALYSES

All the model options were compared using the metrics contained in the Scikit-learn package. The comparison statistics were: Mean Absolute Error (MAE), Mean Squared Error (MSE), Root Mean Squared Error (RMSE), and Mean Absolute Percentage Error (MAPE) following the following formulations

$$MAE = \frac{1}{n}\sum|y - \hat{y}|$$

where n is the number of data points, y is the observed value, $\hat{y}$ is the predicted value. MAE provides an error measurement, but not a direction, overfitting or underfitting, and the calculation does not penalize large errors, since it does not square the calculation.

$$MSE = \frac{1}{n}\sum(y - \hat{y})^2$$

this metric penalizes larger errors, since those will be squared, and when there are higher outliers, the MSE will highlight those values for a fast comparison.

$$RMSE = \sqrt{MSE} = \sqrt{\frac{1}{n}\sum(y - \hat{y})^2}$$

RMSE is a popular metric, since it is derived from MSE, and it would represent a more impactful value than MAE, since a doubling in error in MSE is calculated by a squared function, and not a linear relationship. RMSE values made the comparison easier since the values are not squared, but in a similar dimension as the original or predicted values.

$$MAPE = \frac{1}{n}\sum\left|\frac{y-\hat{y}}{y}\right|$$

in this case the $y - \hat{y}$ portion represents the residual, and by dividing by the observed values, the residual value is being scaled by the observed value. MAPE calculations need to be considered carefully, especially for very small observations values, or when the observed values equal zero, which would make a division by zero.

E. ALGORITHMS

1. LINEAR REGRESSION (LR)

There are several types of regression for scientific use, in this case we explored multiple variable LR since in the ML approach we utilized Air Temperature, Water Temperature, Sea Level Pressure, Relative Humidity, and the wind vectors u and v. The multivariable regression approach allowed us to find a relationship between the independent variables to predict another for a determined time, or a future time

$$\hat{y} = \beta_o + \beta_1 x_1 + \cdots + \beta_p x_p + \varepsilon$$

where $\hat{y}$ is dependent variable (predicted value, or labels), $\beta_o, \beta_1, \ldots, \beta_p$ are regression coefficients, and $x_1, x_2, \ldots, x_p$ are independent variables (inputs, or features) in the

model, and ε is the error (LeCun et al. 2009). LR is suitable approach for continuous values or time series (i.e., weather observations).

2. DECISION TREE (DT)

In a DT, the prediction is arrived by asking a sequence of questions to the data. Depending on how the data responds to the questions, the data is split into two paths from the root node, and a decision node or branch is created, and subsequent questions are asked until the data reaches a terminal node or leaf. In the case of DT regressors, the MSE is used to ask the questions, and the path is taken in the attempt to minimize the MSE on the final answer for the particular set of variables, and the final answer is obtained by a weighted MSE since it depends on the number of samples on the branch. The final prediction is made by averaging the values on the leaf nodes, and the best answer is the one with the lowest weighted MSE and this leaf node averaging. The training data becomes extremely important, since it lays the path that the testing or any other data will take to arrive at the predicted value (Kamiński et al. 2018).

3. RANDOM FOREST (RF)

This algorithm has two principal concepts: Random sampling of the training data when constructing trees, and for splitting nodes, it uses random subsets of features. It uses the meta-algorithm "bagging," which is a compound term of bootstrap aggregating technique, in which the goal is to reduce the prediction's variance, meant to produce an unbiased estimation, and a reduction in the testing error. One way of thinking about RF is as applying the bagging technique to DT; however, instead of having a set criterion or splitting into decision nodes, the splits happen randomly until leaves are reached. This random splitting could benefit heterogenous data, in which there are different units and ranges, as in our case, with temperature, pressure, wind, and humidity (Cornell University 2021).

One benefit of RF is that it takes advantage of being closer, on average, to the actual values, since it depends on several DTs predictions, then those predictions are averaged to get the final result. Taking advantage on the bagging technique, the variance

is reduced, in the expectation that it will reduce bias, resulting in not overfitting (Breiman 2001).

4. TENSORFLOW (TF)

In a simple description of the TF approach, it is a neural network, which works as a set of input and output nodes, separated by hidden node layers. A basic neural network would be composed of three layers (input, hidden, and output). The manner in which the neurons are activated depends on the training steps, since this is where the neurons get their weight values and biases, which after being passed through a nonlinear function such as a rectified linear unit, it is turned on or off. After the training step, once the model is faced with new data, it learns that based on certain conditions, some neuron pathways are activated, and the values are passed on to the next layer, which eventually arrives at a final value, which in this case would be a predicted value. The manner in which the hidden layer calculates the neuron's weights and biases depends on the options selected by the user, and then calculated by the amount of neurons in the layer. However, in the TF approach, the manner in which these calculations are made is hidden from the user, and only some parameters are able to be changed. Even though these options are plenty, experimentation during the training step is needed, and further model tuning may be needed afterwards, in order to be able to let the model make better predictions (LeCun et al. 2015, Brand et al. 2020).

F. BIAS-VARIANCE

The primary goal of ML is to generate a model which is capable of using input data that it has never seen and being able to predict values with a small error from some verifying reality. However, in the search for the smallest error, some of these model approaches tend to overfit the data. This can happen when the model memorizes the path created by the training data, along with the error that it created. One important concept in AI/ML is the bias-variance trade-off. This happens due to the flexibility or inflexibility of the model. A flexible model, in which the training data varies the learned parameters, as occurs in DT models, is considered to be a high variance model. It does not have any biases about the data, and is able to learn new paths; however, those new paths may have

substantial fluctuations from reality. On the other hand, an inflexible model is considered a high bias model, since it is not able to learn new paths, and it has inflexible biases about the data. This bias-variance trade-off must be considered in model approach selection, or while tuning the model (Breiman 2001, LeCun et al. 2015, Kamiński et al. 2018, Brand et al. 2020).

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IV. RESULTS/DISCUSSION

As summarized in Table 5, different algorithms were applied to the three time periods (cases) noted in Figure 23. Recall that the aside from location, the data we use from the different buoys has different frequency of collection (hourly vs. every 15-minutes). Buoy 22 data provided to us have 15 minutes in its data interval; however, data from Buoy 21 was given hourly. Our approach was to use observations to calculate EDH/EDS with NAVSLaM for each observation time, then use those values for training the various algorithms to nowcast EDH/EDS directly. That is, the algorithms were fed training observations of environmental observations and corresponding derived EDH/EDS, and each algorithm came up with its own formulation for an EDH/EDS nowcast. Individual forecasts of the elements used to calculate EDH/EDS were also carried out (temperature, humidity, etc.). Those forecasted elements were then fed to NAVSLaM for an additional EDH/EDS nowcast. In this way, we examine a direct nowcast of EDH/EDS with an EDH/EDS calculated from nowcasts of the elements that NAVSLaM uses for its calculations.

We attempted training the selected algorithms using just one hour of observation before the nowcast, and also using 3 hours of observations, early in the process. Only the algorithms including the prior 3 hours were used, since the metrics were overall better. An alternative, not deeply explored here but of special interest for neural networks, would be to use some additional variant such as using all prior observations (since a ship got underway), or a larger moving window of observations.

Table 5. Forecast variables and techniques in preliminary tests.

	Linear Regression (LR)	**Decision Tree (DT)**	**Random Forest (RF)**	**TensorFlow (TF)**
Buoy 21 Case 1	- Air temperature - Water temperature - Sea level pressure - Relative humidity - u, v - No preprocessing - Scaling factor - EDH/EDS	- Air temperature - Water temperature - Sea level pressure - Relative humidity - u, v - No preprocessing - Scaling factor	- Air temperature - Water temperature - Sea level pressure - Relative humidity - u, v - No preprocessing - Scaling factor	- Air temperature - Water temperature - Sea level pressure - Relative humidity - u, v - No preprocessing - Scaling factor
Buoy 21 Case 2	- Air temperature - Water temperature - Sea level pressure - Relative humidity - u, v - No preprocessing - Scaling factor	- Air temperature - Water temperature - Sea level pressure - Relative humidity - u, v - No preprocessing - Scaling factor - EDH/EDS	- Air temperature - Water temperature - Sea level pressure - Relative humidity - u, v - No preprocessing - Scaling factor	- Air temperature - Water temperature - Sea level pressure - Relative humidity - u, v - No preprocessing - Scaling factor
Buoy 21 Case 3	- Air temperature - Water temperature - Sea level pressure - Relative humidity - u, v - No preprocessing - Scaling factor	- Air temperature - Water temperature - Sea level pressure - Relative humidity - u, v - No preprocessing - Scaling factor	- Air temperature - Water temperature - Sea level pressure - Relative humidity - u, v - No preprocessing - Scaling factor - EDH/EDS	- Air temperature - Water temperature - Sea level pressure - Relative humidity - u, v - No preprocessing - Scaling factor
Buoy 22 Case 1	- Air temperature - Water temperature - Sea level pressure - Relative humidity - u, v - No preprocessing - Scaling factor - EDH/EDS	- Air temperature - Water temperature - Sea level pressure - Relative humidity - u, v - No preprocessing - Scaling factor	- Air temperature - Water temperature - Sea level pressure - Relative humidity - u, v - No preprocessing - Scaling factor	- Air temperature - Water temperature - Sea level pressure - Relative humidity - u, v - No preprocessing - Scaling factor
Buoy 22 Case 2	- Air temperature - Water temperature	- Air temperature - Water temperature	- Air temperature - Water temperature	- Air temperature - Water temperature

	Linear Regression (LR)	**Decision Tree (DT)**	**Random Forest (RF)**	**TensorFlow (TF)**
	- Sea level pressure - Relative humidity - u, v - No preprocessing - Scaling factor	- Sea level pressure - Relative humidity - u, v - No preprocessing - Scaling factor	- Sea level pressure - Relative humidity - u, v - No preprocessing - Scaling factor - EDH/EDS	- Sea level pressure - Relative humidity - u, v - No preprocessing - Scaling factor
Buoy 22 Case 3	- Air temperature - Water temperature - Sea level pressure - Relative humidity - u, v - No preprocessing - Scaling factor	- Air temperature - Water temperature - Sea level pressure - Relative humidity - u, v - No preprocessing - Scaling factor - EDH/EDS	- Air temperature - Water temperature - Sea level pressure - Relative humidity - u, v - No preprocessing - Scaling factor	- Air temperature - Water temperature - Sea level pressure - Relative humidity - u, v - No preprocessing - Scaling factor

The performance of the nowcasts from these approaches were compared against a persistence nowcast (i.e., the observed/analyzed variable value at the beginning of the nowcast period was assumed to stay constant for the following 6 hours). To gauge best performance, the main metric used was RMSE. If two-techniques had very close RMSE, as tie breakers MSE, MAE, and MAPE were examined. All nowcasts were compared with each other and against buoy observations. For each case and technique, if at least one metric was better for an ML approach than for persistence forecast, it would be considered for further validation and testing. The best performing algorithm during each case/time period was noted. The best performing algorithm during each case/time period was noted, and the nowcast by that model were used for NAVSLaM calculations as well. All of the ML metrics tables are presented in the Appendix.

A. BUOY 21 CASE 1

For Buoy 21, Case 1, specifically for air temperature, TF with no scale factor and using the 3 preceding hours of observations to make a nowcast had smaller error than using persistence. LR with no scale factor and using the prior 3 hours of observations

performed better than persistence for water temperature. It was noted that LR had better overall metrics than TF for all remaining features, and it was used for NAVSLaM EDH/ EDS calculations. Table 6 summarizes the performance statistics for air and water temperature specifically.

Table 6. Buoy 21 Case1 ML nowcast vs. persistence comparison.

CASE 1			
Air Temperature (C) persistence model error		NOWCAST CASE1 NO SCALE PRIOR3	
Root Mean Squared Error (RMSE)	0.666	TF Air Temperature 6hr forecast model error (C)	
		Root Mean Squared Error (RMSE)	0.384
Water Temperature (C) persistence model error		NOWCAST CASE1 NO SCALE PRIOR3	
Root Mean Squared Error (RMSE)	0.181	LR Water Temperature 6hr forecast model error (C)	
		Root Mean Squared Error (RMSE)	0.149

The resulting EDH calculation from NAVSLaM utilizing the LR nowcast features resulted in an RMSE greater than 2 m, and EDS RMSE greater than 8 M-units (Table 7). If we couple these values with the MAPE, we can observe that both EDH and EDS values had greater than 20% absolute percentage error. The plot for NAVSLaM calculated EDH/EDS values are displayed in Figures 24 to 27. On these figures we observed that the EDH nowcast appears to roughly lag observations by three hours, and the EDS nowcast values are lower than those from observations.

Table 7. Buoy 21 Case 1 NAVSLaM EDH/EDS metrics. The nowcast variables are input to NAVSLaM to calculate EDH/EDS.

EDH (m)		EDS (M-units)	
Mean Absolute Error (MAE)	1.750	Mean Absolute Error (MAE)	8.154
Mean Squared Error (MSE)	4.108	Mean Squared Error (MSE)	73.118
Root Mean Squared Error (RMSE)	2.027	Root Mean Squared Error (RMSE)	8.551
Mean Absolute Percentage Error (MAPE)	0.207	Mean Absolute Percentage Error (MAPE)	0.265

MSE values are squared units.

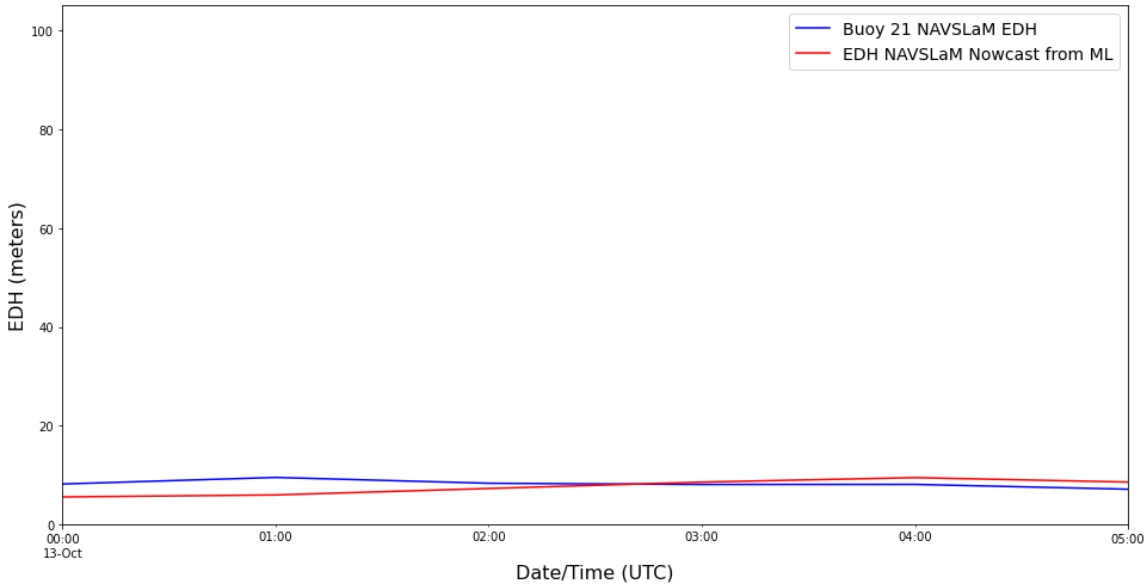

Figure 24. Buoy 21 Case 1 (13 Oct 2017) NAVSLaM EDH. The blue line represents the EDH calculated from NAVSLaM using measured data as input. The red line denotes EDH calculated from NAVSLaM using the ML forecast variables as input.

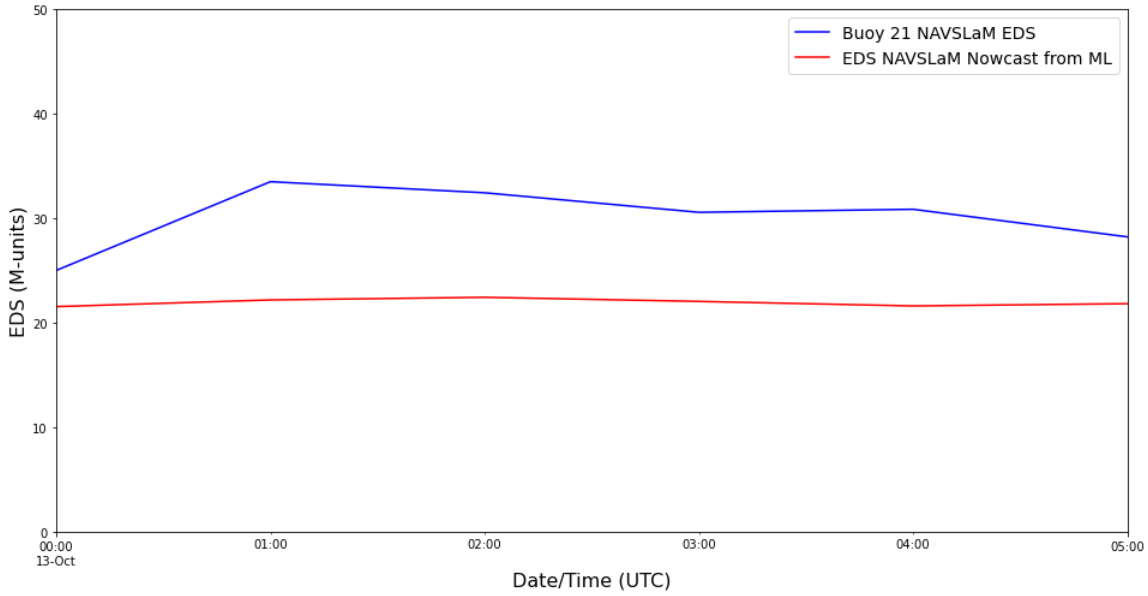

Figure 25. Buoy 21 Case 1 (13 Oct 2017) NAVSLaM EDS. The blue line represents the EDS calculated from NAVSLaM using measured data as input. The red line denotes EDS calculated from NAVSLaM using the ML forecast variables as input.

Comparison of the calculated NAVSLaM EDH/EDS with the direct EDH/EDS nowcast showed that both techniques were comparable; however, the direct EDS nowcast had better RMSE values, and based on the MSE, the outliers were closer to the observed values.

Table 8. Buoy 21 Case 1 LR direct EDH/EDS nowcast metrics.

EDH (m)		EDS (M-units)	
Mean Absolute Error (MAE)	1.697	Mean Absolute Error (MAE)	4.134
Mean Squared Error (MSE)	4.097	Mean Squared Error (MSE)	18.230
Root Mean Squared Error (RMSE)	2.024	Root Mean Squared Error (RMSE)	4.270
Mean Absolute Percentage Error (MAPE)	0.200	Mean Absolute Percentage Error (MAPE)	0.137

MSE values are squared units.

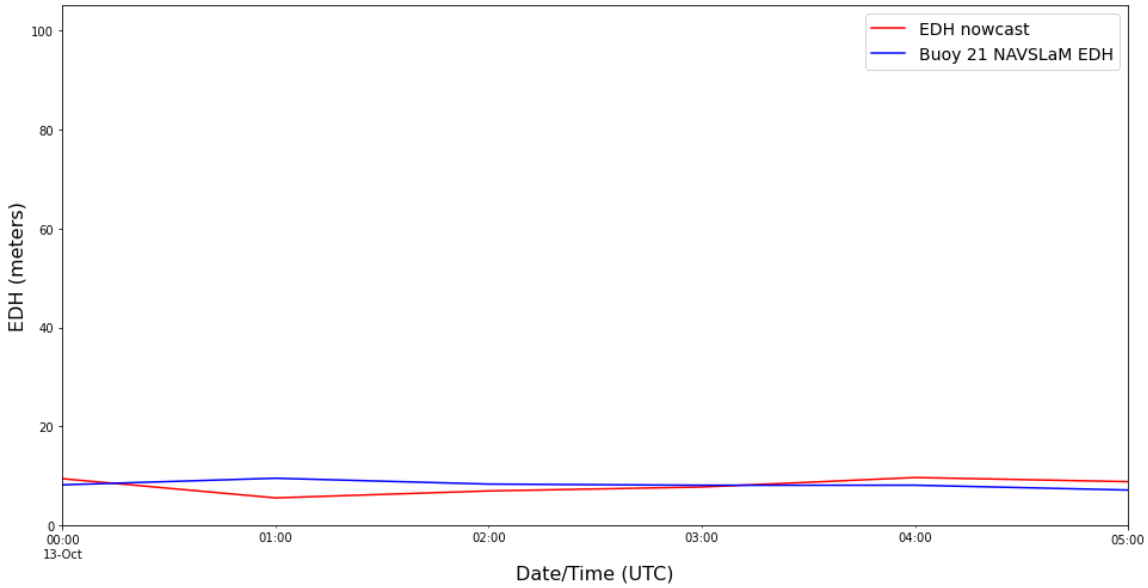

Figure 26. Buoy 21 Case 1 (13 Oct 2017) LR direct EDH nowcast.

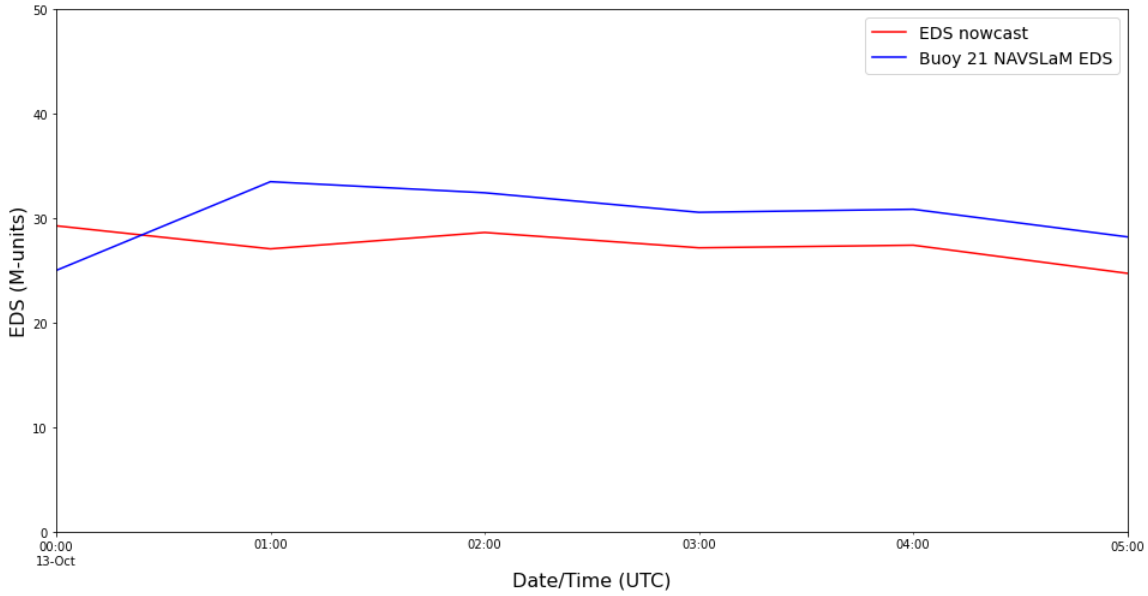

Figure 27. Buoy 21 Case 1 (13 Oct 2017) LR direct EDH nowcast.

B. BUOY 21 CASE 2

For Buoy 21, Case 2 (Table 9), DT with no scale factor and using the prior 3 hours of data was the best performer for the u (east-west) wind component. Additionally, DT with no scale factor and prior 3 hours of data had the best overall metrics, and it was used for NAVSLaM EDH/EDS calculations.

Table 9. Buoy 21 Case2 ML nowcast vs. persistence comparison.

CASE 2			
u (m s^{-1}) persistence model error		NOWCAST CASE2 NO SCALE PRIOR3	
Root Mean Squared Error (RMSE)	4.442	DT u 6hr forecast model error (m s^{-1})	
		Root Mean Squared Error (RMSE)	2.136
		NOWCAST CASE2 SCALE PRIOR3	
		DT u 6hr forecast model error (m s^{-1})	
		Root Mean Squared Error (RMSE)	2.483
		NOWCAST CASE2 NO SCALE PRIOR3	
		RF u 6hr forecast model error (m s^{-1})	
		Root Mean Squared Error (RMSE)	2.446
		NOWCAST CASE2 SCALE PRIOR3	
		RF u 6hr forecast model error (m s^{-1})	
		Root Mean Squared Error (RMSE)	2.331
		NOWCAST CASE2 NO SCALE PRIOR3	
		TF u 6hr forecast model error (m s^{-1})	
		Root Mean Squared Error (RMSE)	3.266
		NOWCAST CASE2 SCALE PRIOR3	
		TF u 6hr forecast model error (m s^{-1})	
		Root Mean Squared Error (RMSE)	3.022

The resulting EDH calculation from NAVSLaM utilizing the DT nowcast features resulted in an EDH RMSE greater than 11 m, and EDS RMSE greater than 4 M-units (Table 10). If we also examine MAPE, we can observe that EDH values were greater than 80% in absolute percentage error, and MAPE EDS values were greater than 21%. In the plotted data for NAVSLaM calculated EDH/EDS values we observed the overforecast for EDH, and EDS.

Table 10. Buoy 21 Case 2 NAVSLaM EDH/EDS metrics. The nowcast variables are input to NAVSLaM to calculate EDH/EDS.

EDH (m)		EDS (M-units)	
Mean Absolute Error (MAE)	10.335	Mean Absolute Error (MAE)	3.812
Mean Squared Error (MSE)	132.538	Mean Squared Error (MSE)	16.481
Root Mean Squared Error (RMSE)	11.513	Root Mean Squared Error (RMSE)	4.060
Mean Absolute Percentage Error (MAPE)	0.846	Mean Absolute Percentage Error (MAPE)	0.218

MSE values are squared units.

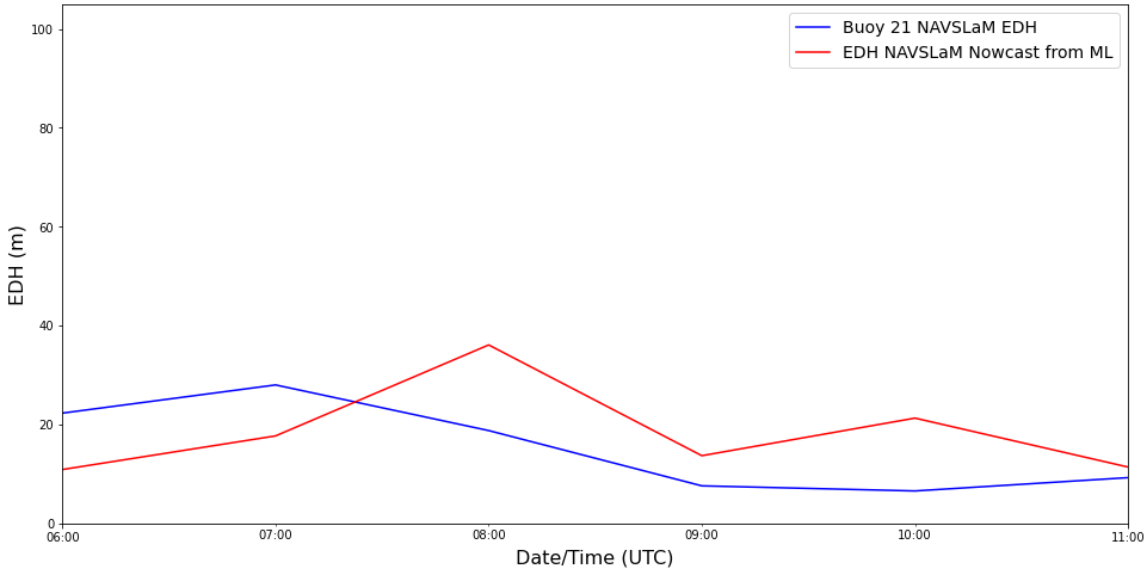

Figure 28. Buoy 21 Case 2 (21 Oct 2017) NAVSLaM EDH. The blue line represents the EDH calculated from NAVSLaM using measured data as input. The red line denotes EDH calculated from NAVSLaM using the ML forecast variables as input.

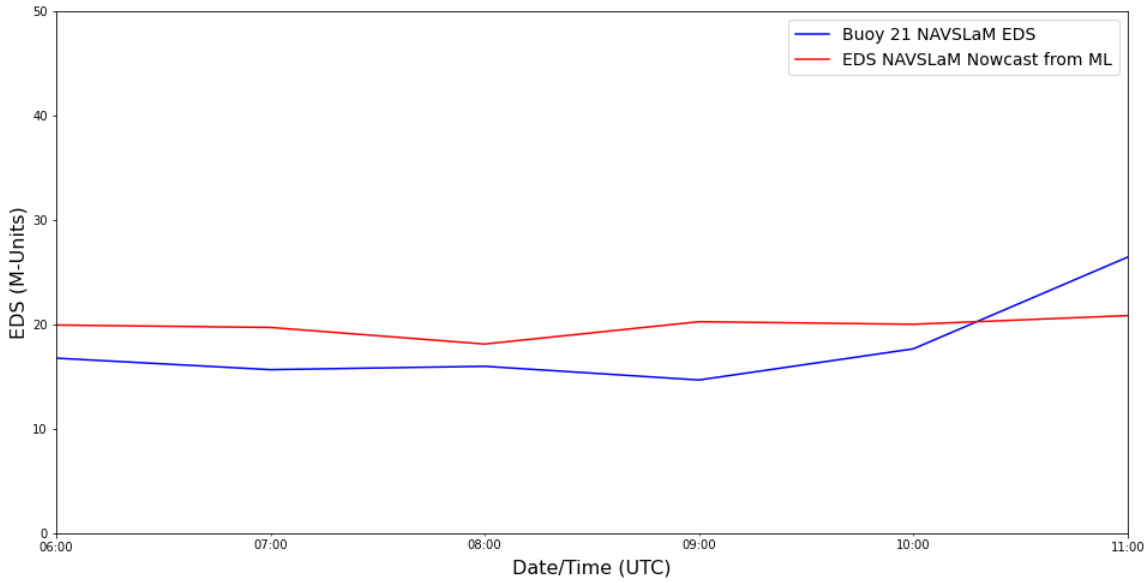

Figure 29. Buoy 21 Case 2 (21 Oct 2017) NAVSLaM EDS. The blue line represents the EDS calculated from NAVSLaM using measured data as input. The red line denotes EDS calculated from NAVSLaM using the ML forecast variables as input.

The comparison between the calculated NAVSLaM EDH/EDS values and the direct EDH/EDS nowcast showed an overforecast for both EDH/EDS direct nowcast approach, by a large margin.

Table 11. Buoy 21 Case 2 DT direct EDH/EDS nowcast metrics.

EDH (m)		EDS (M-units)	
Mean Absolute Error (MAE)	39.950	Mean Absolute Error (MAE)	14.875
Mean Squared Error (MSE)	2925.727	Mean Squared Error (MSE)	235.452
Root Mean Squared Error (RMSE)	54.090	Root Mean Squared Error (RMSE)	15.344
Mean Absolute Percentage Error (MAPE)	5.077	Mean Absolute Percentage Error (MAPE)	0.900

MSE values are squared units.

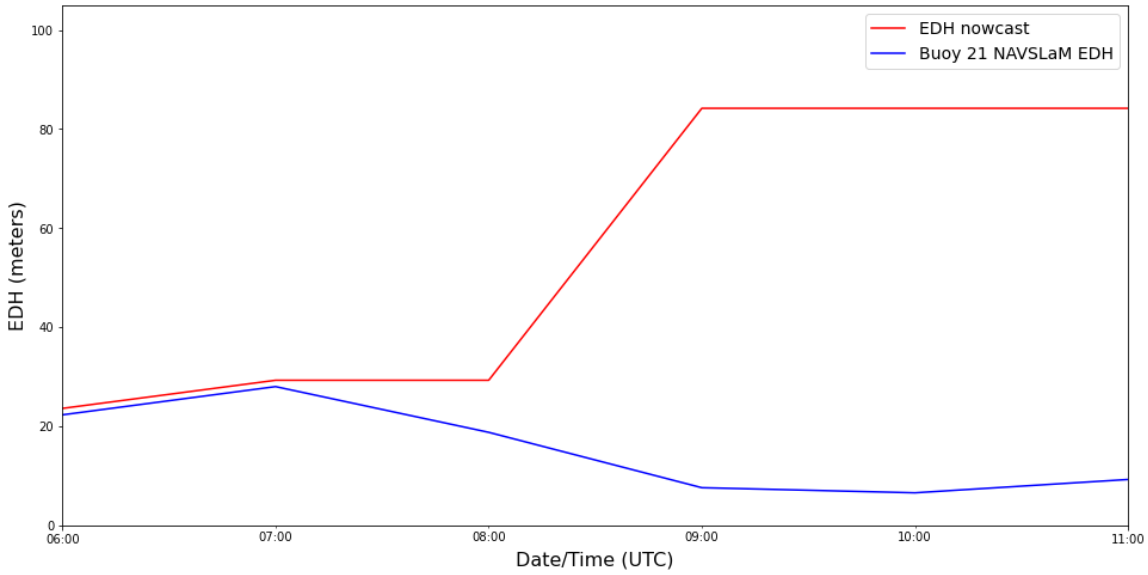

Figure 30. Buoy 21 Case 2 (21 Oct 2017) DT direct EDH nowcast.

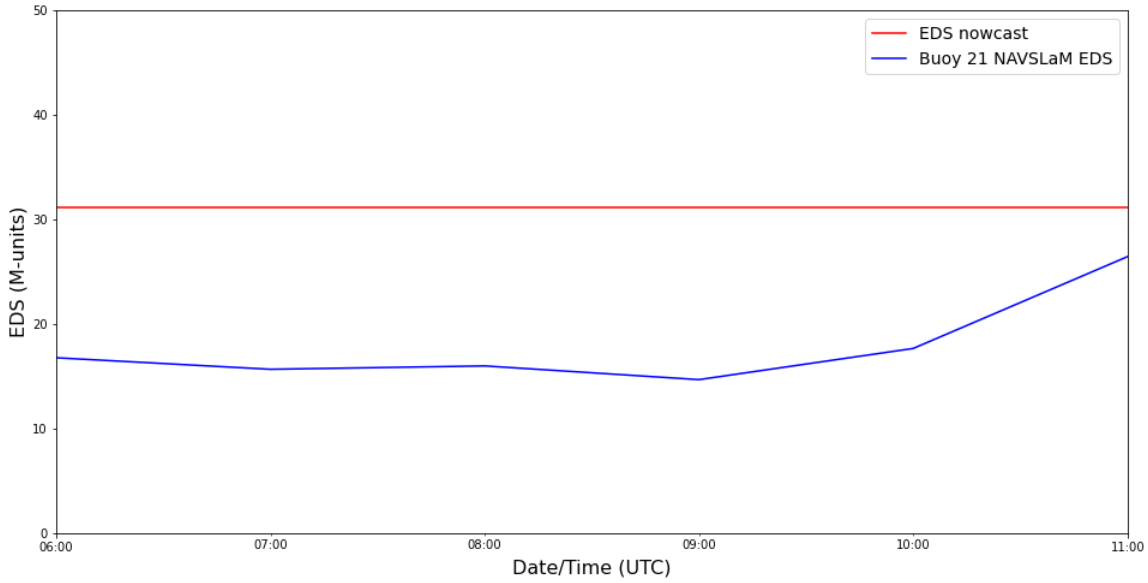

Figure 31. Buoy 21 Case 2 (21 Oct 2017) DT direct EDS nowcast.

C. BUOY 21 CASE 3

For Buoy 21, Case 3 (Table 12), RF with no scale factor and prior 3 hours was the best performer for the air temperature feature. TF approach also performed well;

however, RF with no scale factor and prior 3 hours had the better overall metrics, and it was used for NAVSLaM EDH/EDS calculations.

Table 12. Buoy 21 Case3 ML nowcast vs. persistence comparison.

CASE 3			
Air Temperature (C) persistence model error		NOWCAST CASE3 NO SCALE PRIOR3	
Root Mean Squared Error (RMSE)	1.030	RF Air Temperature 6hr forecast model error (C)	
		Root Mean Squared Error (RMSE)	0.791
		NOWCAST CASE3 NO SCALE PRIOR3	
		TF Air Temperature 6hr forecast model error (C)	
		Root Mean Squared Error (RMSE)	0.821

The resulting EDH calculation from NAVSLaM utilizing the RF nowcast features resulted in an RMSE greater than 56 m, and EDS RMSE greater than 18 M-units. If we couple these values with the MAPE, we can observe that EDH values were greater than 200% in absolute percentage error, and MAPE EDS values were almost 40%. The rest of the metrics provided a better insight into the fit for this nowcast, and from the plotted data, we can observe a large disparity in the EDH nowcast comparison with the calculated EDH from buoy observations. For EDS, we observed a large underforecast from the plotted data, and the metrics backed up the disagreement with the calculated EDS from buoy observations. On Case 3, there were only five hours available for comparison due to the missing data on the Buoy 21 EDH/EDS calculations.

Table 13. Buoy 21 Case 3 NAVSLaM EDH/EDS metrics. The nowcast variables are input to NAVSLaM to calculate EDH/EDS.

EDH (m)		EDS (M-units)	
Mean Absolute Error (MAE)	49.398	Mean Absolute Error (MAE)	17.468
Mean Squared Error (MSE)	3207.888	Mean Squared Error (MSE)	347.258
Root Mean Squared Error (RMSE)	56.638	Root Mean Squared Error (RMSE)	18.635
Mean Absolute Percentage Error (MAPE)	2.418	Mean Absolute Percentage Error (MAPE)	0.397

MSE values are squared units.

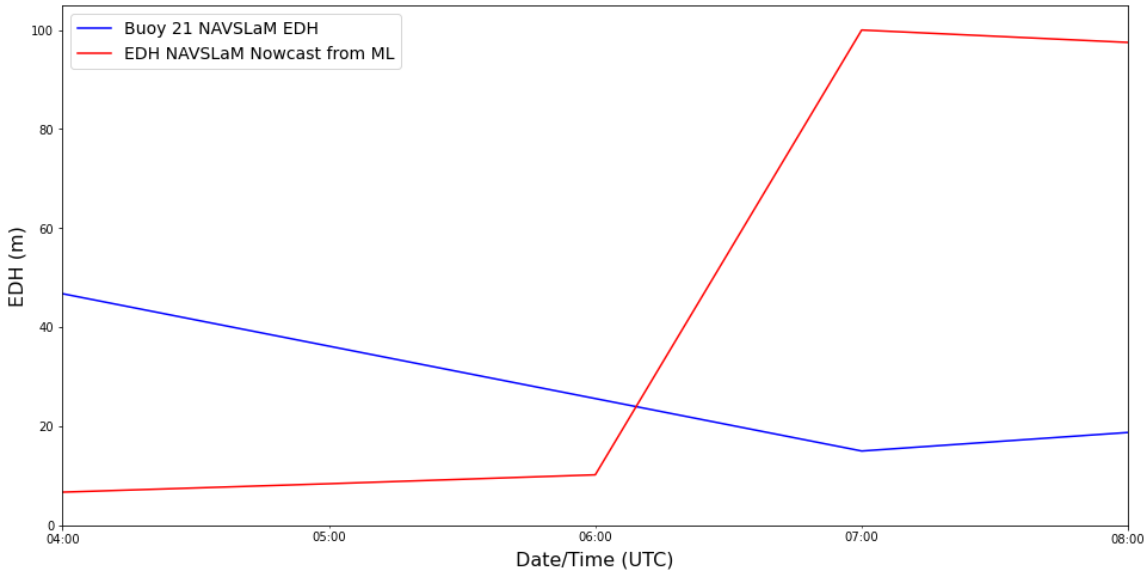

Figure 32. Buoy 21 Case 3 (26 Oct 2017) NAVSLaM EDH. The blue line represents the EDH calculated from NAVSLaM using measured data as input. The red line denotes EDH calculated from NAVSLaM using the ML forecast variables as input.

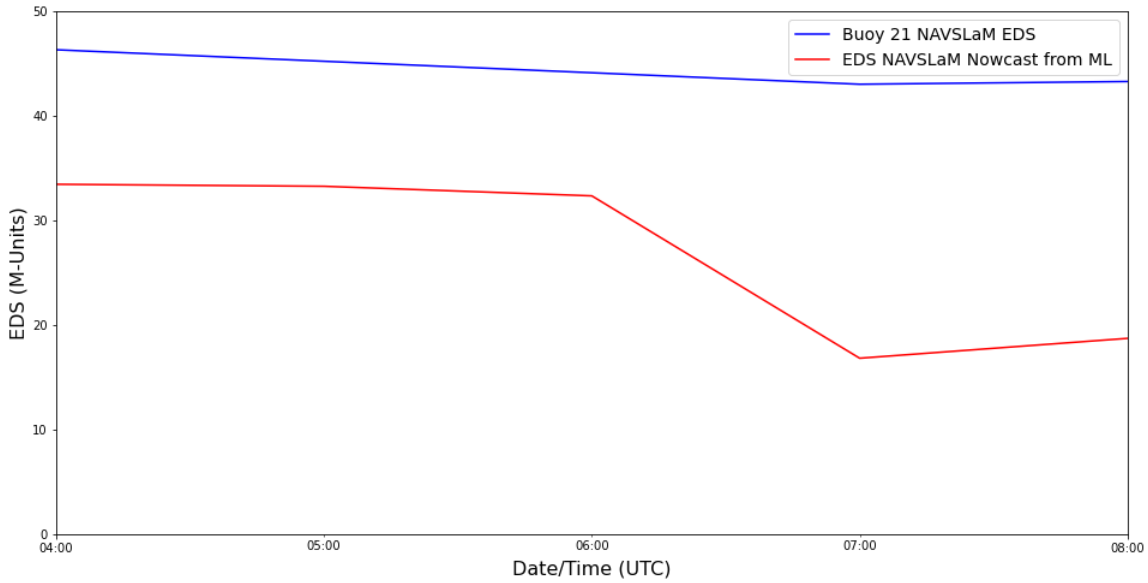

Figure 33. Buoy 21 Case 3 (26 Oct 2017) NAVSLaM EDS. The blue line represents the EDS calculated from NAVSLaM using measured data as input. The red line denotes EDS calculated from NAVSLaM using the ML forecast variables as input.

The comparison between the calculated NAVSLaM EDH/EDS values and the direct EDH/EDS nowcast showed an overforecast for EDH, and underforecast for EDS direct nowcast approach; however, the outliers on the direct nowcast approach were closer to the observed values (Figures 34, 35). (On the direct nowcast approach, there were only five data points to compare).

Table 14. Buoy 21 Case 3 RF direct EDH/EDS nowcast metrics.

EDH (m)		EDS (M-units)	
Mean Absolute Error (MAE)	17.638	Mean Absolute Error (MAE)	4.645
Mean Squared Error (MSE)	449.358	Mean Squared Error (MSE)	27.501
Root Mean Squared Error (RMSE)	21.198	Root Mean Squared Error (RMSE)	5.244
Mean Absolute Percentage Error (MAPE)	0.847	Mean Absolute Percentage Error (MAPE)	0.102

MSE values are squared units.

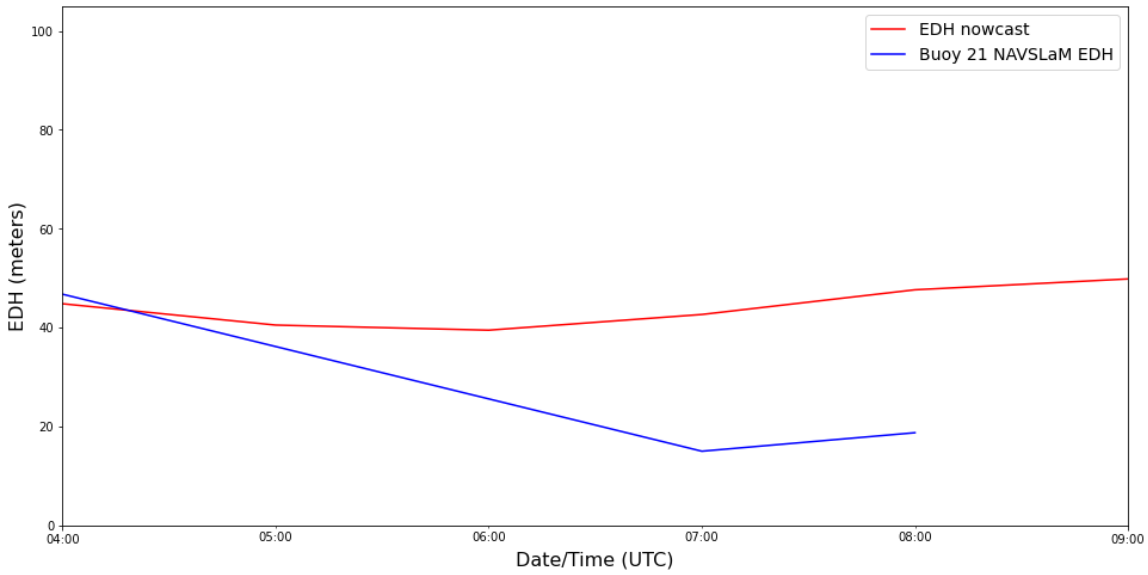

Figure 34. Buoy 21 Case 3 (26 Oct 2017) RF direct EDH nowcast.

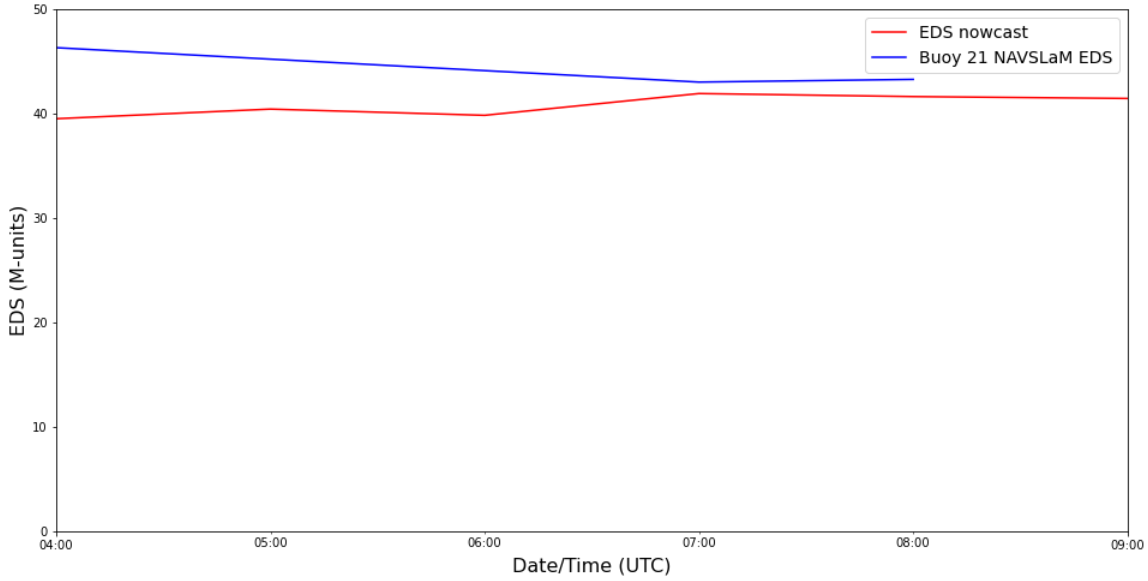

Figure 35. Buoy 21 Case 3 (26 Oct 2017) RF direct EDS nowcast.

D. BUOY 21 SUMMARY

The MAPE for all Buoy 21 cases was relatively large, which in part may be attributed to small training sets. Using only hourly data and breaking up the total dataset into three cases severely limits the number of training data points. However, that the techniques can at least beat persistence is suggestive that with more training data, additional skill might be gained. It is also interesting to note that as case complexity increased, the relative complexity of the ML algorithm used increased. For example, as noted diurnal variation and relatively lower winds were experienced during Case 1, and the best ML algorithm was the relatively simple multi-linear regression. Case 2 saw an increase in wind speeds generally, arguably making the air-sea interaction more complex, and was better captured by a (arguably) more complicated decision tree. Case 3 was the most distinct time period of the three cases, with strong dry winds associated with a Santa Ana Wind event. This complicated meteorological setting was better captured by the variations in a random forest model. Variations in trends (Figures 26, 27, and 29) were qualitatively consistent between nowcast and analyzed EDH/EDS, for case 2 and case 3 over several hours.

E. BUOY 22 CASE 1

For Buoy 22, Case 1 (Table 8), LR and TF with no scale factor and prior 3 hours performed better than the persistence for relative humidity. Note, Buoy 21 and 22 were in near proximity though different locations, and recall that we use observations every 15 minutes for Buoy 22, and the data was averaged hourly for comparison with Buoy 21. Even though TF's metric for relative humidity was better than LR, LR had better overall metrics than TF for the remainder features, and it was used for NAVSLaM EDH/EDS calculations.

Table 15. Buoy 22 Case1 ML nowcast vs. persistence comparison.

CASE 1			
Relative Humidity (%) persistence model error		NOWCAST CASE1 NO SCALE PRIOR3	
Root Mean Squared Error (RMSE)	4.729	LR Relative Humidity 6hr forecast model error (%)	
		Root Mean Squared Error (RMSE)	4.687
		NOWCAST CASE1 NO SCALE PRIOR3	
		TF Relative Humidity 6hr forecast model error (%)	
		Root Mean Squared Error (RMSE)	3.698

The resulting EDH calculation from NAVSLaM utilizing the LR nowcast features resulted in an RMSE greater than 2 m, and EDS RMSE greater than 3 M-units (EDH were to Buoy 21; however, EDS was better on Buoy 22). If we couple these values with the MAPE, we can observe that EDH values were greater than 35% in absolute percentage error, and MAPE EDS values were greater than 12%. The rest of the metrics provided a better insight into the fit for this nowcast, and from the plotted data, we can observe a slight overforecast in the EDH nowcast. For EDS, we observed a slight underforecast from the plotted data, and the metrics backed up the low disagreement with the calculated EDS from buoy observations. (Due to feature engineering there were only five data points to compare, since there was one missing data point, Figures 36, 37).

Table 16. Buoy 22 Case 1 NAVSLaM EDH/EDS metrics. The nowcast variables are input to NAVSLaM to calculate EDH/EDS.

EDH (m)		EDS (M-units)	
Mean Absolute Error (MAE)	2.259	Mean Absolute Error (MAE)	2.725
Mean Squared Error (MSE)	6.054	Mean Squared Error (MSE)	12.219
Root Mean Squared Error (RMSE)	2.46	Root Mean Squared Error (RMSE)	3.496
Mean Absolute Percentage Error (MAPE)	0.358	Mean Absolute Percentage Error (MAPE)	0.123

MSE values are squared units.

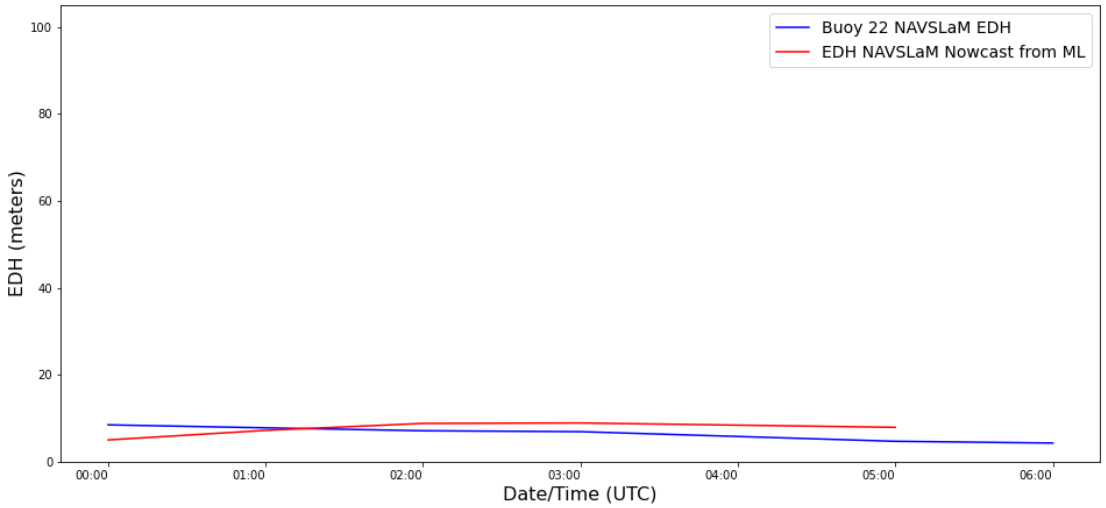

Figure 36. Buoy 22 Case 1 (13 Oct 2017) NAVSLaM EDH. The blue line represents the EDH calculated from NAVSLaM using measured data as input. The red line denotes EDH calculated from NAVSLaM using the ML forecast variables as input.

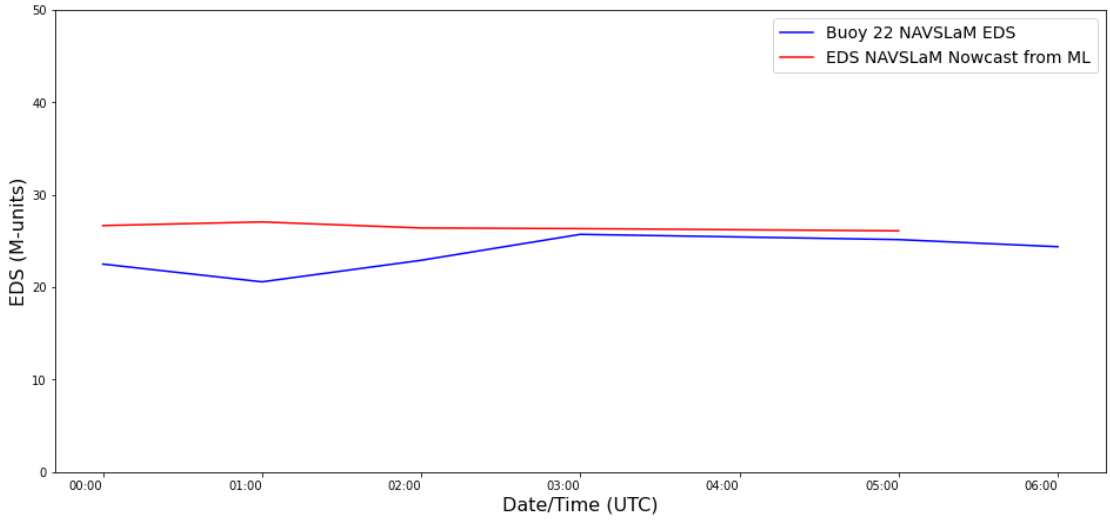

Figure 37. Buoy 22 Case 1 (13 Oct 2017) NAVSLaM EDS. The blue line represents the EDS calculated from NAVSLaM using measured data as input. The red line denotes EDS calculated from NAVSLaM using the ML forecast variables as input.

The comparison between the NAVSLaM calculated EDH/EDS and the direct EDH/EDS nowcast showed an overforecast for EDH, and underforecast for EDS direct nowcast approach; however, the direct nowcast approach was not an improvement on the EDS nowcast. (On the direct nowcast approach, there were only five data points to compare, since there was one missing data point, but it was interpolated, Figures 38, 39).

Table 17. Buoy 22 Case 1 direct EDH/EDS nowcast metrics.

EDH (m)		EDS (M-units)	
Mean Absolute Error (MAE)	1.808	Mean Absolute Error (MAE)	4.595
Mean Squared Error (MSE)	4.375	Mean Squared Error (MSE)	32.483
Root Mean Squared Error (RMSE)	2.092	Root Mean Squared Error (RMSE)	5.699
Mean Absolute Percentage Error (MAPE)	0.307	Mean Absolute Percentage Error (MAPE)	0.206

MSE values are squared units.

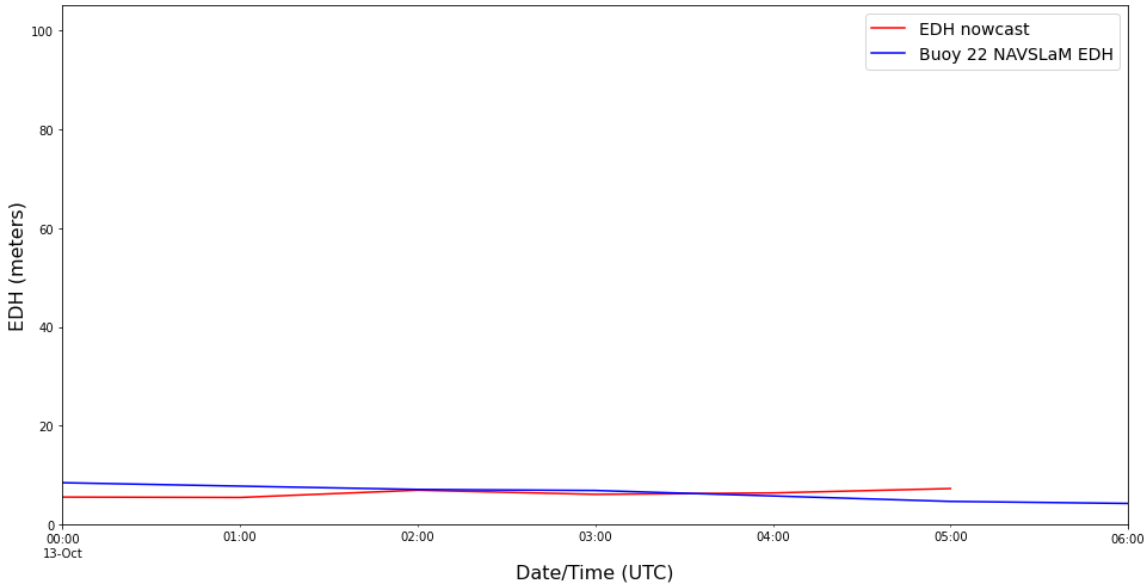

Figure 38. Buoy 22 Case 1 (13 Oct 2017) direct EDH nowcast.

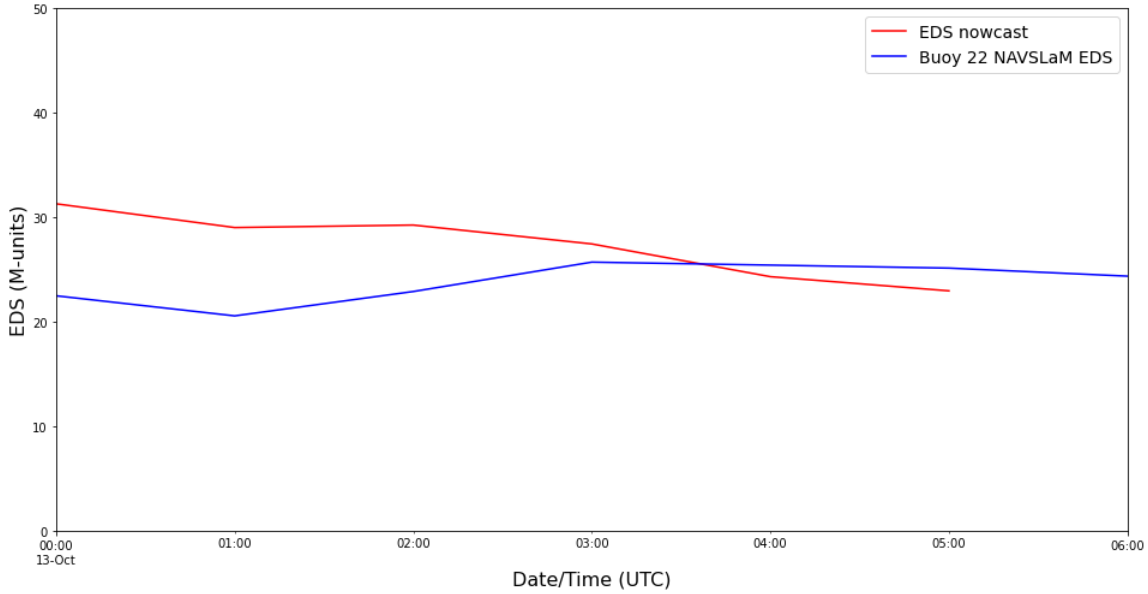

Figure 39. Buoy 22 Case 1 (13 Oct 2017) direct EDS nowcast.

F. BUOY 22 CASE 2

For Buoy 22, Case 2 (Table 9), LR and RF with no scale factor and prior 3 hours were the best performer for the v feature. Also, RF with no scale factor and prior 3 hours

performed well for the u feature. RF had better overall metrics than LR, and it was used for NAVSLaM EDH/EDS calculations.

Table 18. Buoy 22 Case 2 ML nowcast vs. persistence comparison.

CASE 2			
v (m s^{-1}) persistence model error		NOWCAST CASE2 NO SCALE PRIOR3	
Root Mean Squared Error (RMSE)	2.251	LR v 6hr forecast model error (m s^{-1})	
		Root Mean Squared Error (RMSE)	2.115
		NOWCAST CASE2 NO SCALE PRIOR3	
		RF v 6hr forecast model error (m s^{-1})	
		Root Mean Squared Error (RMSE)	1.535
u (m s^{-1}) persistence model error		NOWCAST CASE2 NO SCALE PRIOR3	
Root Mean Squared Error (RMSE)	4.256	RF u 6hr forecast model error (m s^{-1})	
		Root Mean Squared Error (RMSE)	2.475

The resulting EDH calculation from NAVSLaM utilizing the RF nowcast features resulted in an RMSE of near 2 m, and EDS RMSE greater than 4 M-units (Buoy 22 showed an improvement on EDH values, and similar metrics for EDS as Buoy 21). If we couple these values with the MAPE, we can observe that EDH values were greater than 16% in absolute percentage error, and MAPE EDS values were near 9%. The rest of the metrics provided a better insight into the fit for this nowcast, and from the plotted data, we can observe a slight underforecast in the EDH nowcast (Figure 40). For EDS (Figure 41), we observed a slight overforecast from the plotted data, and the metrics backed up the relatively low disagreement with the calculated EDH/EDS from buoy observations.

Table 19. Buoy 22 Case 2 NAVSLaM EDH/EDS metrics. The nowcast variables are input to NAVSLaM to calculate EDH/EDS.

EDH (m)		EDS (M-units)	
Mean Absolute Error (MAE)	1.672	Mean Absolute Error (MAE)	2.889
Mean Squared Error (MSE)	3.795	Mean Squared Error (MSE)	17.228
Root Mean Squared Error (RMSE)	1.948	Root Mean Squared Error (RMSE)	4.151
Mean Absolute Percentage Error (MAPE)	0.166	Mean Absolute Percentage Error (MAPE)	0.088

MSE values are squared units.

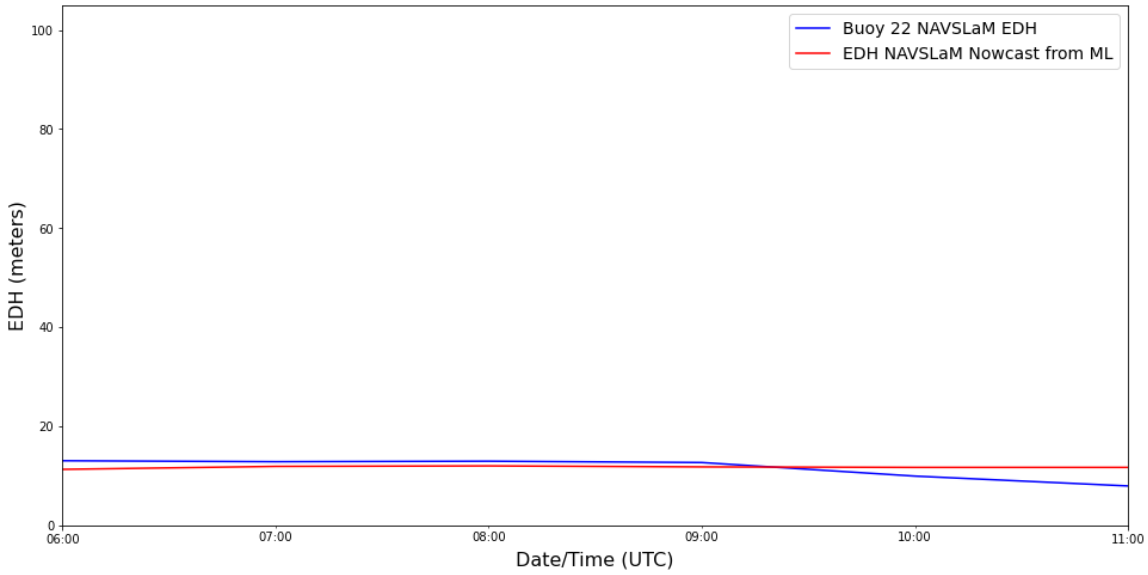

Figure 40. Buoy 22 Case 2 (21 Oct 2017) NAVSLaM EDH. The blue line represents the EDH calculated from NAVSLaM using measured data as input. The red line denotes EDH calculated from NAVSLaM using the ML forecast variables as input.

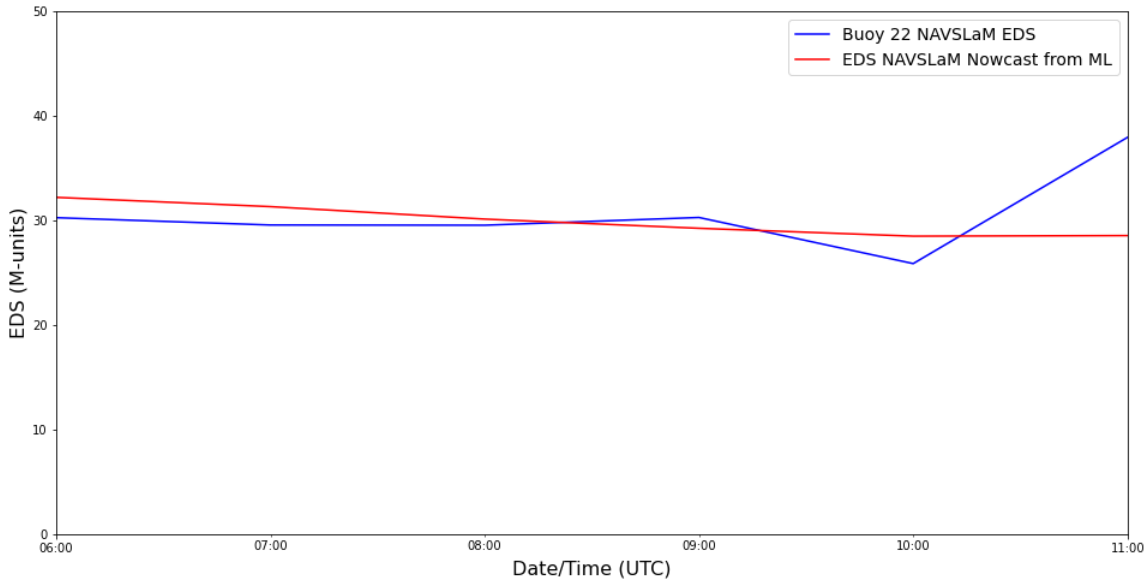

Figure 41. Buoy 22 Case 2 (21 Oct 2017) NAVSLaM EDS. The blue line represents the EDS calculated from NAVSLaM using measured data as input. The red line denotes EDS calculated from NAVSLaM using the ML forecast variables as input.

The metrics values from the direct nowcast approach (Table 20) were not better than the EDH/EDS values from the nowcast obtained by the calculated NAVSLaM EDH/ EDS, and it showed a larger difference from the observed values (Figures 42, 43).

Table 20. Buoy 22 Case 2 direct EDH/EDS nowcast metrics.

EDH (m)		EDS (M-units)	
Mean Absolute Error (MAE)	2.195	Mean Absolute Error (MAE)	4.489
Mean Squared Error (MSE)	8.983	Mean Squared Error (MSE)	22.584
Root Mean Squared Error (RMSE)	2.997	Root Mean Squared Error (RMSE)	4.752
Mean Absolute Percentage Error (MAPE)	0.233	Mean Absolute Percentage Error (MAPE)	0.150

MSE values are squared units.

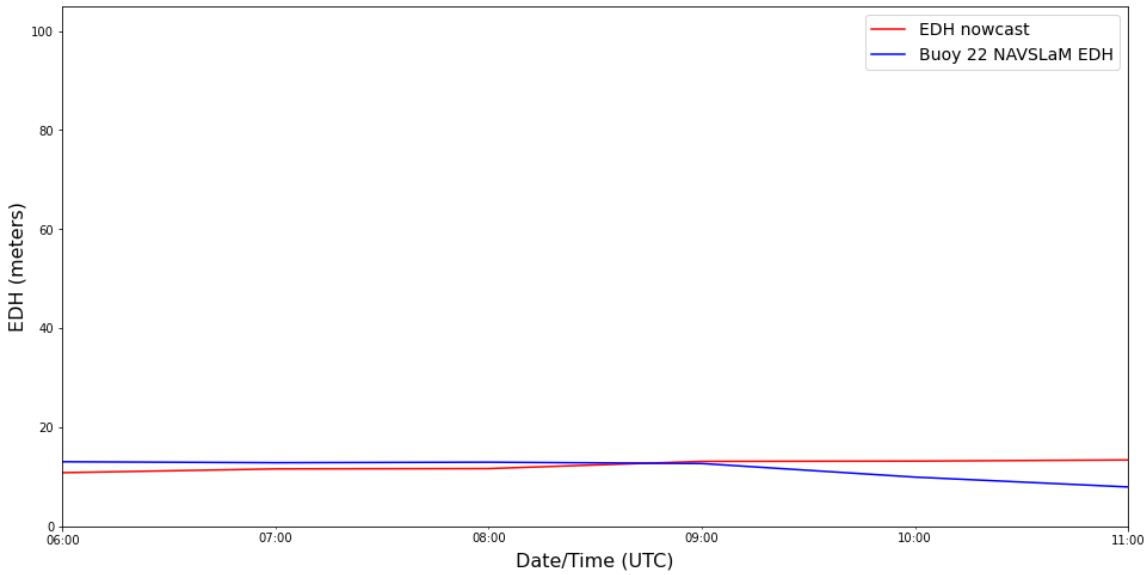

Figure 42. Buoy 22 Case 2 (21 Oct 2017) direct EDH nowcast.

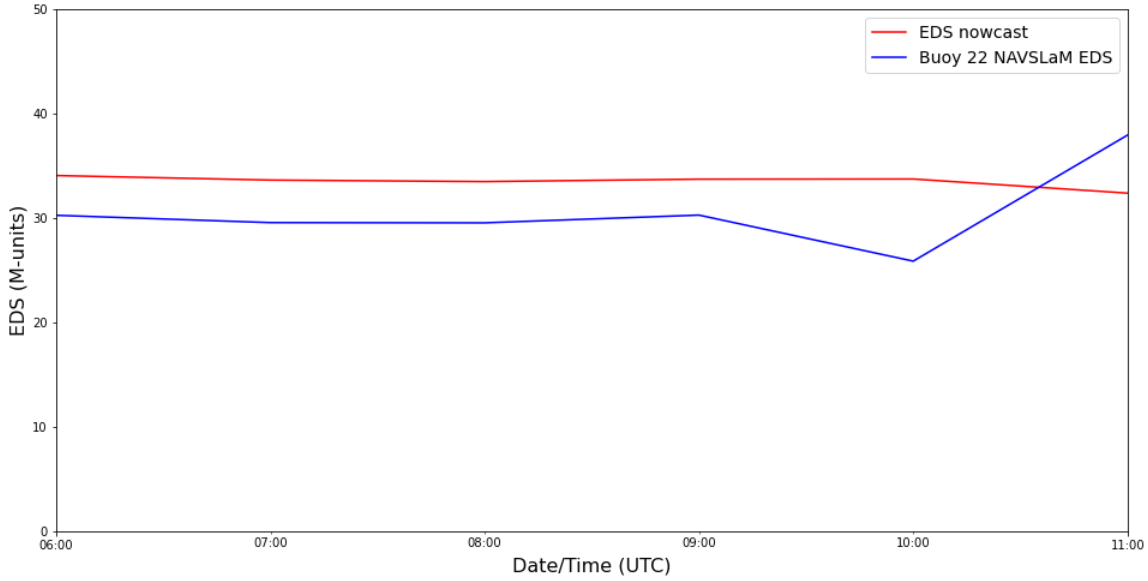

Figure 43. Buoy 22 Case 2 (21 Oct 2017) direct EDS nowcast.

G. BUOY 22 CASE 3

For Buoy 22, Case 3 (Table 10), all four ML with no scale factor and prior 3 hours performed better than the persistence for the relative humidity feature. DT with no scale factor and prior 3 hours had the better overall metrics, and it was used for NAVSLaM EDH/EDS calculations.

Table 21. Buoy 22 Case3 ML nowcast vs. persistence comparison.

CASE 3			
Relative Humidity (%) persistence model error		NOWCAST CASE3 NO SCALE PRIOR3	
Root Mean Squared Error (RMSE)	7.699	LR Relative Humidity 6hr forecast model error (%)	
		Root Mean Squared Error (RMSE)	6.090
		NOWCAST CASE3 NO SCALE PRIOR3	
		DT Relative Humidity 6hr forecast model error (%)	
		Root Mean Squared Error (RMSE)	7.415
		NOWCAST CASE3 NO SCALE PRIOR3	
		RF Relative Humidity 6hr forecast model error (%)	
		Root Mean Squared Error (RMSE)	5.441
		NOWCAST CASE3 NO SCALE PRIOR3	
		TF Relative Humidity 6hr forecast model error (%)	
		Root Mean Squared Error (RMSE)	4.891
Water Temperature (C) persistence model error		NOWCAST CASE3 NO SCALE PRIOR3	
Root Mean Squared Error (RMSE)	0.402	TF Water Temperature 6hr forecast model error (C)	
		Root Mean Squared Error (RMSE)	0.352
Air Temperature (C) persistence model error		NOWCAST CASE3 NO SCALE PRIOR3	
Root Mean Squared Error (RMSE)	0.534	DT Air Temperature 6hr forecast model error (C)	
		Root Mean Squared Error (RMSE)	0.531

The resulting EDH calculation from NAVSLaM utilizing the DT nowcast features resulted in an RMSE of near 80 m, and EDS RMSE near 10 M-units (Buoy 21 showed better metrics for EDH, but not for EDS). If we couple these values with the MAPE, we can observe that EDH values were greater than 90% in absolute percentage error, and MAPE EDS values were near 22%. The rest of the metrics provided a better insight into the fit for this nowcast, and from the plotted data, we can observe a significant underforecast in the EDH nowcast (Figure 44). For EDS (Figure 45), we observed a large overforecast from the plotted data, and the metrics backed up the disagreement with the calculated EDH/EDS from buoy observations, with MSE providing an insight into the outlying data, since values are exaggerated for outliers.

Table 22. Buoy 22 Case 3 NAVSLaM EDH/EDS metrics. The nowcast variables are input to NAVSLaM to calculate EDH/EDS.

EDH (m) (only 5hrs available)		EDS (M-units) (only 5hrs available)	
Mean Absolute Error (MAE)	80.465	Mean Absolute Error (MAE)	9.802
Mean Squared Error (MSE)	6479.789	Mean Squared Error (MSE)	99.439
Root Mean Squared Error (RMSE)	80.497	Root Mean Squared Error (RMSE)	9.972
Mean Absolute Percentage Error (MAPE)	0.905	Mean Absolute Percentage Error (MAPE)	0.215

MSE values are squared units.

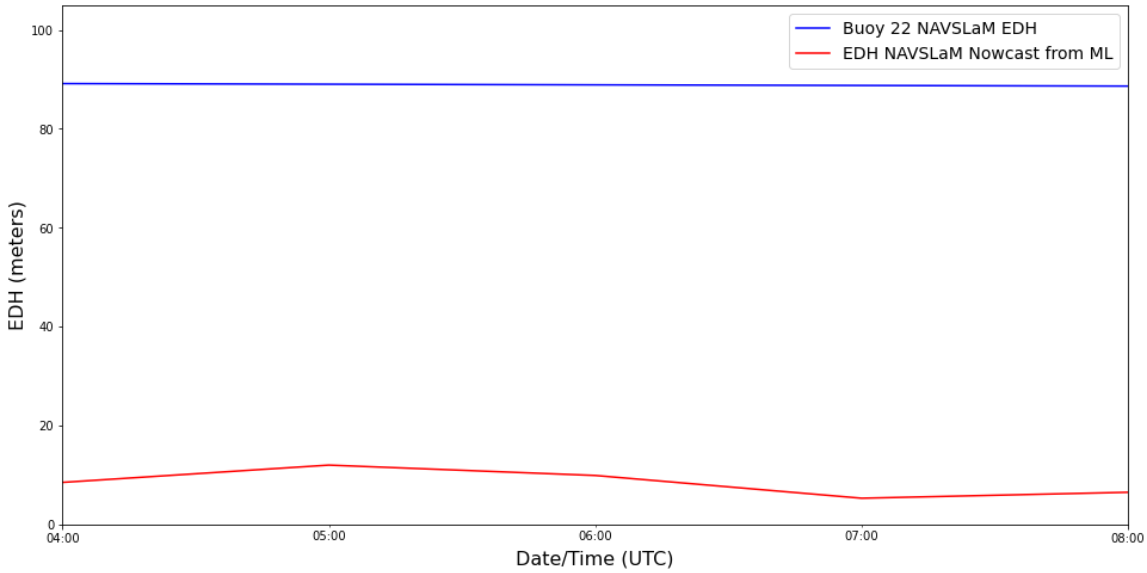

Figure 44. Buoy 22 Case 3 (26 Oct 2017) NAVSLaM EDH. The blue line represents the EDH calculated from NAVSLaM using measured data as input. The red line denotes EDH calculated from NAVSLaM using the ML forecast variables as input.

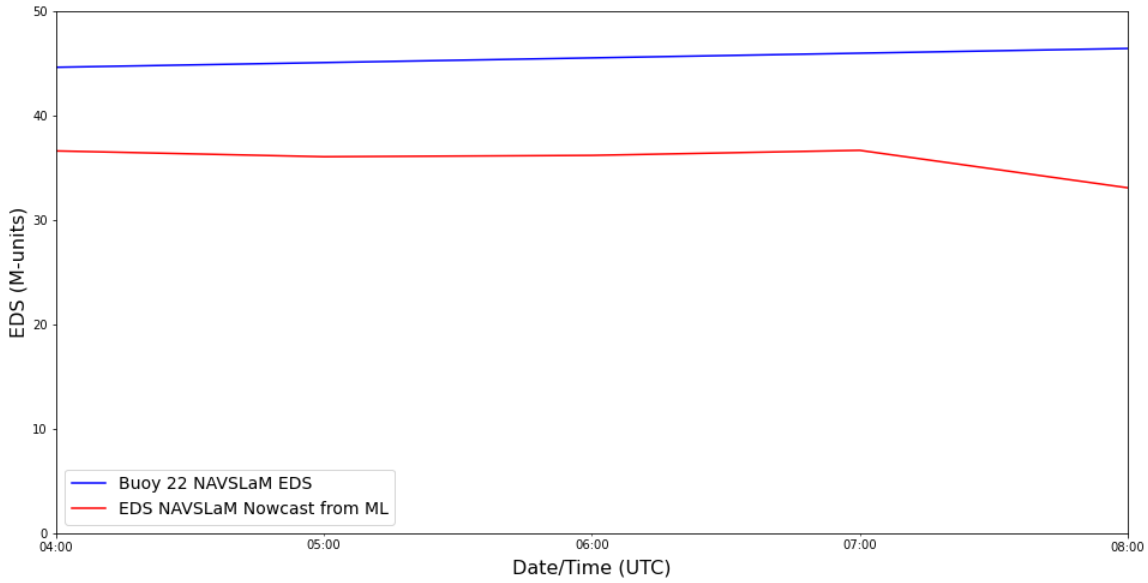

Figure 45. Buoy 22 Case 3 (26 Oct 2017) NAVSLaM EDS. The blue line represents the EDS calculated from NAVSLaM using measured data as input. The red line denotes EDS calculated from NAVSLaM using the ML forecast variables as input.

The direct nowcast approach showed better overall metrics; however, both approaches showed a clear underforecast. Buoy 22 was located further offshore than Buoy 21, and more on the path of the Santa Ana event, which affected the EDH/EDS, and created difficulties for the ML approaches. (On the direct nowcast approach, there were only five data points to compare, since there was one missing data point; Figures 46, 47).

Table 23. Buoy 22 Case 3 direct EDH/EDS nowcast metrics.

EDH (m)		EDS (M-units)	
Mean Absolute Error (MAE)	49.322	Mean Absolute Error (MAE)	5.960
Mean Squared Error (MSE)	2568.026	Mean Squared Error (MSE)	43.453
Root Mean Squared Error (RMSE)	50.676	Root Mean Squared Error (RMSE)	6.592
Mean Absolute Percentage Error (MAPE)	0.737	Mean Absolute Percentage Error (MAPE)	0.151

MSE values are squared units.

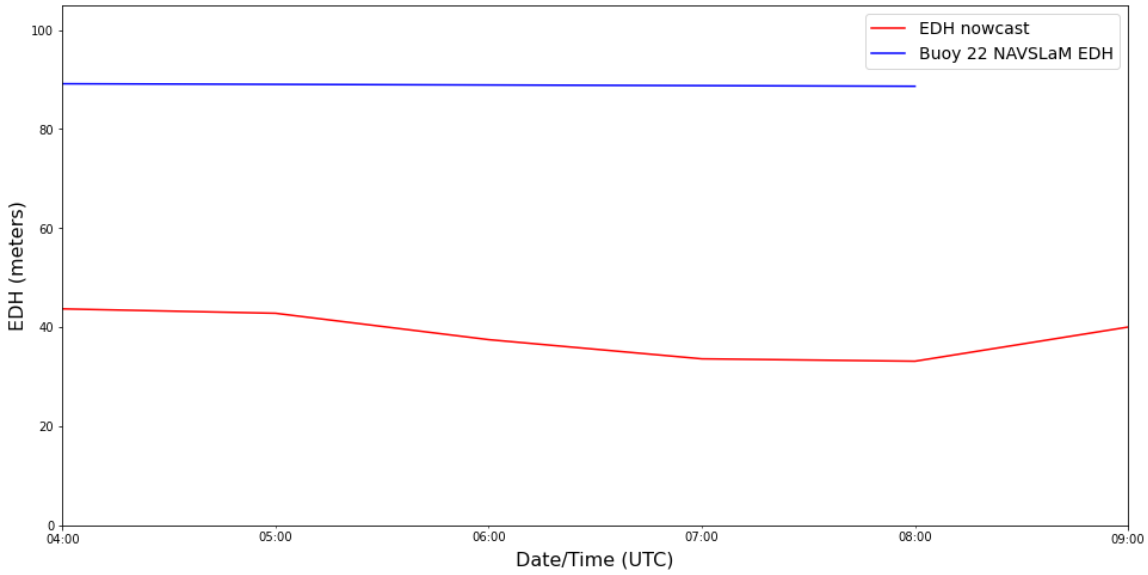

Figure 46. Buoy 22 Case 3 (26 Oct 2017) direct EDH nowcast.

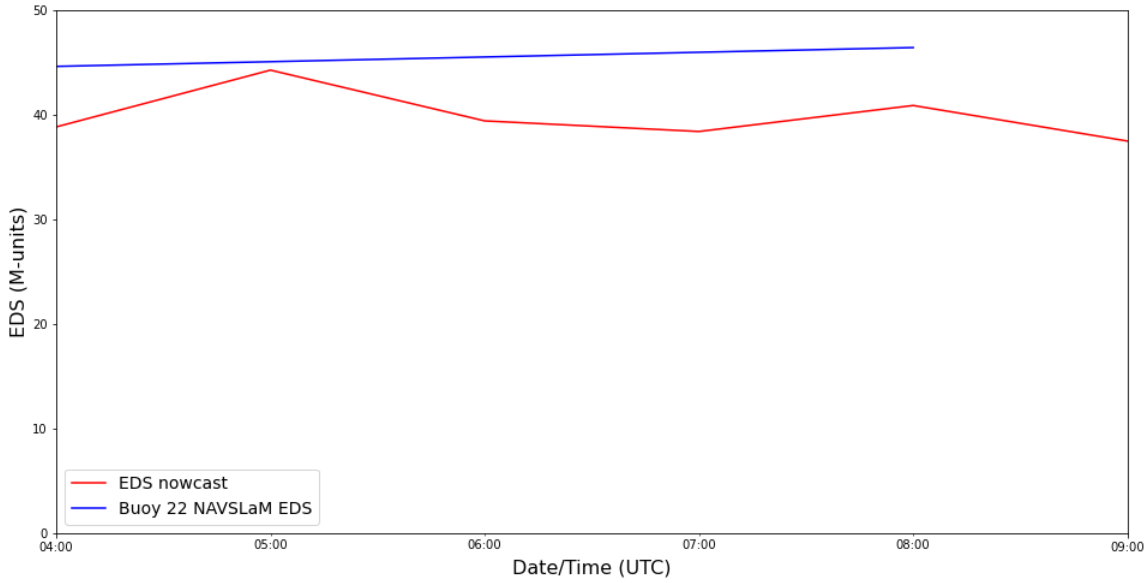

Figure 47. Buoy 22 Case 3 (26 Oct 2017) direct EDS nowcast.

H. BUOY 22 SUMMARY

AI/ML techniques applied using observations for Buoy 22 were best able to predict the CASPER case 2 conditions. LR was again the algorithm of choice for case 1, but did not dramatically outperform nowcasts using hourly data from Buoy 21. As for

Case 3, approaches for both buoy datasets with both AI/ML techniques struggled, which as noted above included more complex atmospheric conditions from the other cases.

I. OVERALL CASE SUMMARY

That AI/ML algorithms are able to beat persistence in predicting several variables is a step towards demonstrating nowcast feasibility. Putting aside case 3, the use of 15-minute data averaged hourly from Buoy 22 did improve error metrics (reference Tables 21–23). Relatively distinct atmospheric conditions experienced during CASPER West motivated the three different case periods. However, dividing roughly 730 hours (or 2920 15-min time periods) into 3 cases, then having to use an 80%/20% training/testing split of the data, took this project out of the realm of "big data" in which AI/ML is expected to best perform. Although a rich dataset, higher frequency observations or a longer observing period may have improved performance. Variations considered, but not shown here, were to not use cases but train drawing from the whole dataset, with the training data selected randomly or simply the first 80% of the observations. However, in the second case, that would have meant that distinctly non-Santa Ana training data would be used to train algorithms, and be tested during a Santa Ana.

V. SUMMARY AND CONCLUSIONS

Overall, the AI/ML approaches explored in this study provided great insight into some limitations of LR, DT, RF, and TF, with the numbers of observations, parameters and frequencies of collection in the datasets used. Although AI/ML was able to provide physically plausible answers, the small number of cases and limited dataset sizes examined here do not allow for an unambiguous assessment of its skill potential. An initial concept for this research was to use non-traditional electromagnetic and electro-optical observations from CASPER. Given time constraints, it was decided to stick to traditional weather observations as input data, as the EM/EO data were often collected episodically, and generally for shorter time periods than the buoy observations we used. This project should be viewed as a demonstration of concept: "off-the-shelf" algorithms can be applied to real-time data, to make plausible predictions in the nowcast time window.

With an eye toward shipboard computational feasibility, given more data AI/ML could be better trained and tuned for emergent consistent biases. The model runs take less than 30 seconds to run once the data files are set up for LR, DT, and RF; TF model runs could take up to seven minutes, but those nowcasts are expected to be much better once more data is ingested. One benefit of the AI/ML modeling approach may be that as a ship navigates around the world, in a shipboard operationally bust environment, the user does not have to be intimately familiar with the workings of the model to be able to choose the best answer. The AI/ML model would be able to rely on the patterns created by the observed and ingested data as it is used for training and testing. On the limitations front especially when using for TF and RF, since there are multiple options to tune the models, a user would have to be cognizant of these options to get a usable result. In the case of LR and DT, the options for the model are more limited and a nowcast is more straightforward.

The nowcast predictions by TF with scaling factors provided the most unreasonable values, for example relative Humidity of greater than 100%, Sea Level Pressure of 1400 hPa. We could have tuned the model more, but keeping in mind a

shipboard scenario, we wanted to assess the most naïve, simply chosen model outputs. The options in TF modeling technique are vast, and the final model has to be tuned appropriately, which requires more experience in how the options affect the weights/bias in the neurons. Also, the number of layers and neurons in them affects the results, possibly making TF, even as adaptable as it is, not the best choice for shipboard use at this time, due to the possible model tuning required. The expectation was that due to the neuron network being able to have better adaptability, TF would provide the best forecast; however, this was not the case initially. Since the model is very adaptable, the expectation was that as more data was ingested, the model would adapt better, which would work well with a ship at sea continually collecting and ingesting more data. This may still be possible, but was not able to be further explored in this project. Overall, TF was not able to tuned appropriately for sea level pressure, on the testing data forecasts, and the TF approach provided answers which were not atmospherically plausible for the drop or rise in pressure values (Appendix E). This may ultimately be due to too small training datasets.

A. FUTURE WORK

As noted above, we were unable to utilize several types of observations from the CASPER data pool. A future thesis student should be able to apply the code base developed here for more work. CASPER had another field campaign off shore of Duck NC in Oct 2015. Hence additional cases could be studied with similar approach. Perhaps most importantly, that future student or students could resolve how to pull into the developed algorithms the EM/EO observations that were a main feature of CASPER. For a real ship underway, radio and radar performance are de facto sampled at high frequency (sub-second, vice hourly) even before leaving a pier, correlated to the atmosphere, and could quickly build up a huge dataset, higher sampling frequency is an aspect that needs to be considered.

With our hourly data, the predicted variability of the forecast parameters (air temperature, water temperature, pressure, relative humidity, and wind) and the model approach could be enhanced by having certain limits on some features (i.e., pressure may

not rise or fall by a certain amount in one hour, or water temperature may not exceed 40 ^{o}C). This method would make sure that the forecast is closer to reality, or that is applying more basic atmospheric dynamics.

An additional project could be to train models on the FLIP data, and explore the variability based on location to serve as a proxy for a geographically dispersed group of ships. In practical terms, how large an area can one machine learning algorithm nowcast be considered valid for (which we expect to vary with time, geometry of multiple collections, types of collected data, and other factors). For submarine forces, it may be an interesting proposition once this nowcast method is validated, since it may be able to be utilized with a minimal sensor suite on the periscope, to be able to sample the atmosphere and verify EDH prior to surfacing.

One approach of choice is the Automated Regression Integrated Moving Average (ARIMA), and this could be processed every time new data is collected after a certain period (every 24 hours could be used as a start). A different method that could be explored is Long Short Term Memory (LSTM), which is a recurrent neural network. This approach takes advantage of feedback connections within the neurons.

Another possibility is that since we looked at environmental features forecast separately, multiple algorithms could be used (one for each variable), and the best performing algorithms output from each could be entered in to NAVSLaM for EDH/EDS comparisons with real observations or calculations from observations.

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APPENDIX. DATA RESULTS

All of the AI/ML model methods were graphically analyzed in the same manner; however, for brevity only tables of error metrics will be displayed (with the exception of LR Case 1 testing, as an example).

A. EXAMPLE OF ANALYSIS DONE FOR EACH ML/AI METHOD – LINEAR REGRESSION CASE 1 PRIOR 3 – NO SCALE

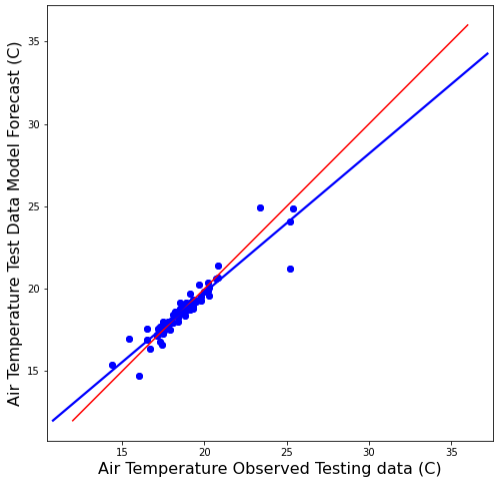

Figure 48. Buoy 21 Air Temperature LR Case1 prior 3 Test Data – No scale factor, Red line 1-to-1 linear relationship, Blue line best line fit.

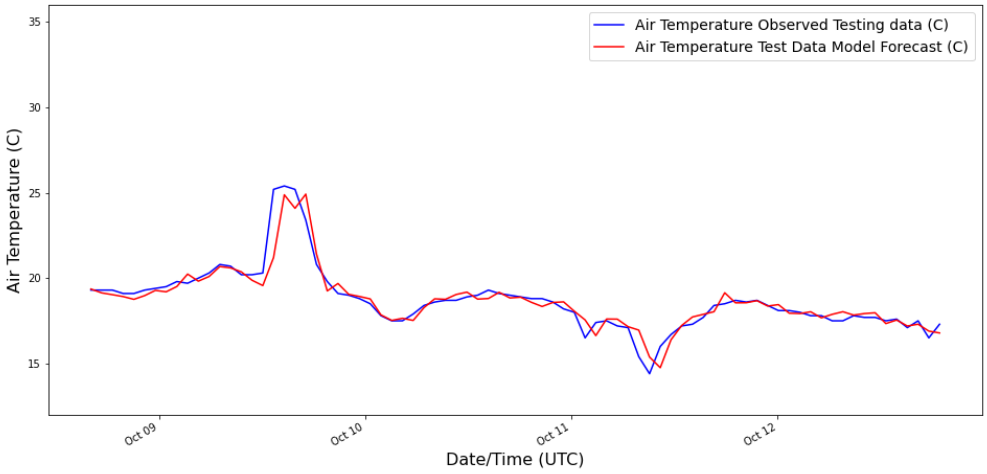

Figure 49. Buoy 21 air temperature LR Case1 prior 3 observed vs. test forecast– No scale factor.

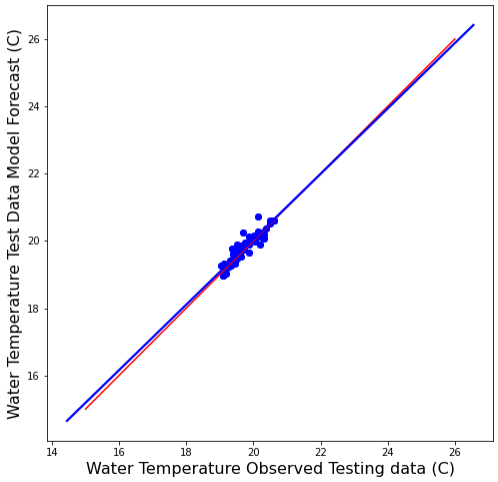

Figure 50. Buoy 21 water temperature LR Case1 prior 3 Test Data – No scale factor, Red line 1-to-1 linear relationship, Blue line best line fit.

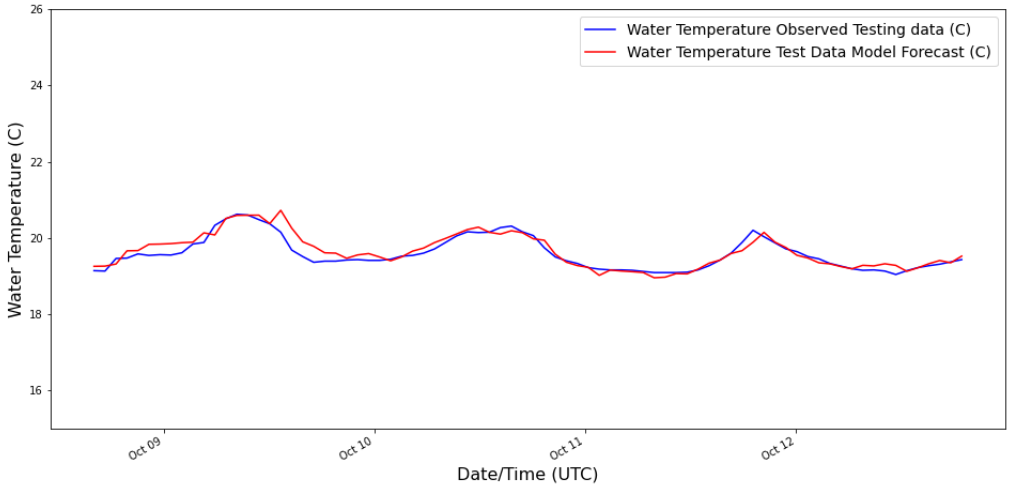

Figure 51. Buoy 21 water temperature LR Case1 prior 3 observed vs. test forecast – No scale factor.

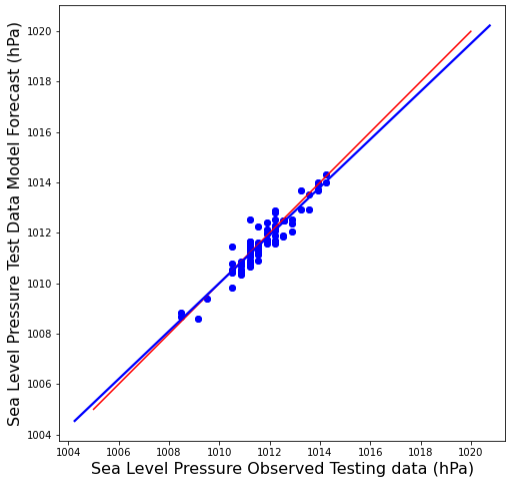

Figure 52. Buoy 21 sea level pressure LR Case1 prior 3 test data – No scale factor, Red line 1-to-1 linear relationship, Blue line best line fit.

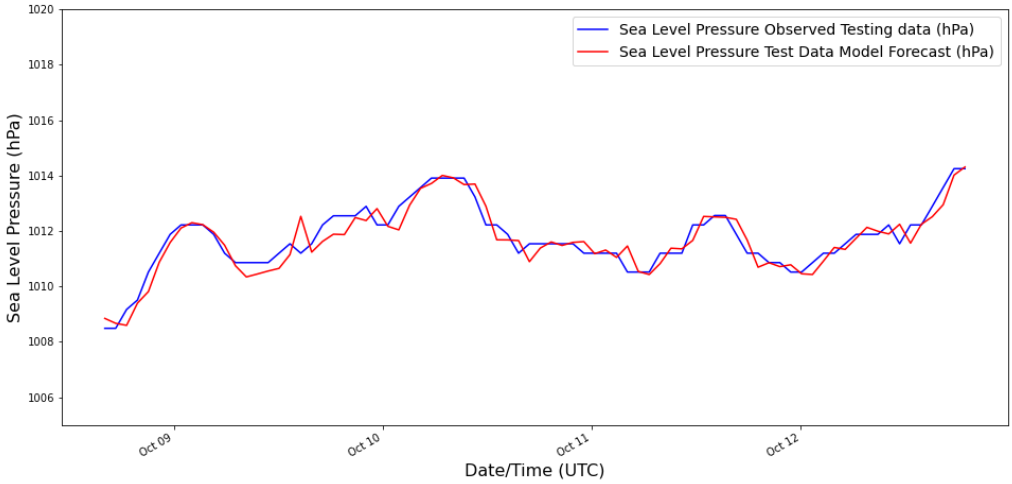

Figure 53. Buoy 21 sea level pressure LR Case1 prior 3 observed vs. test forecast – No scale factor.

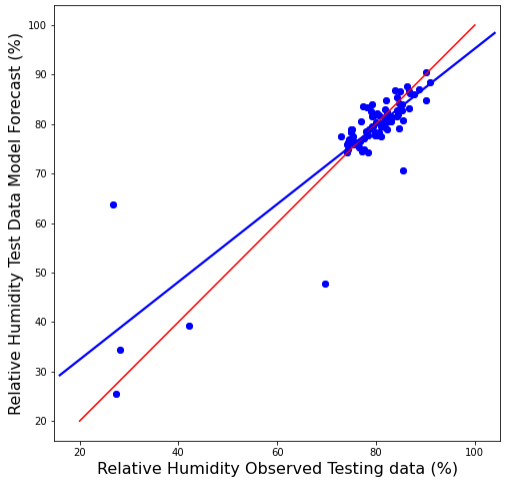

Figure 54. Buoy 21 relative humidity LR Case1 prior 3 test data – No scale factor, Red line 1-to-1 linear relationship, Blue line best line fit.

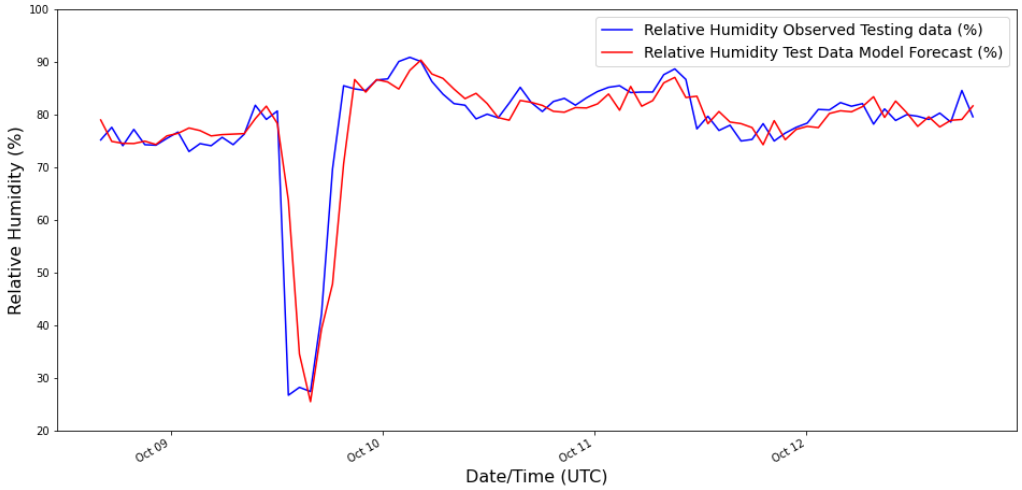

Figure 55. Buoy 21 relative humidity LR Case1 prior 3 observed vs. test forecast – No scale factor.

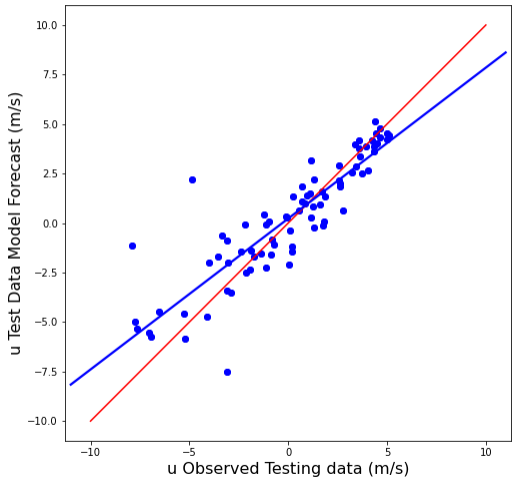

Figure 56. Buoy 21 u LR Case1 prior 3 test data – No scale factor, Red line 1-to-1 linear relationship, Blue line best line fit.

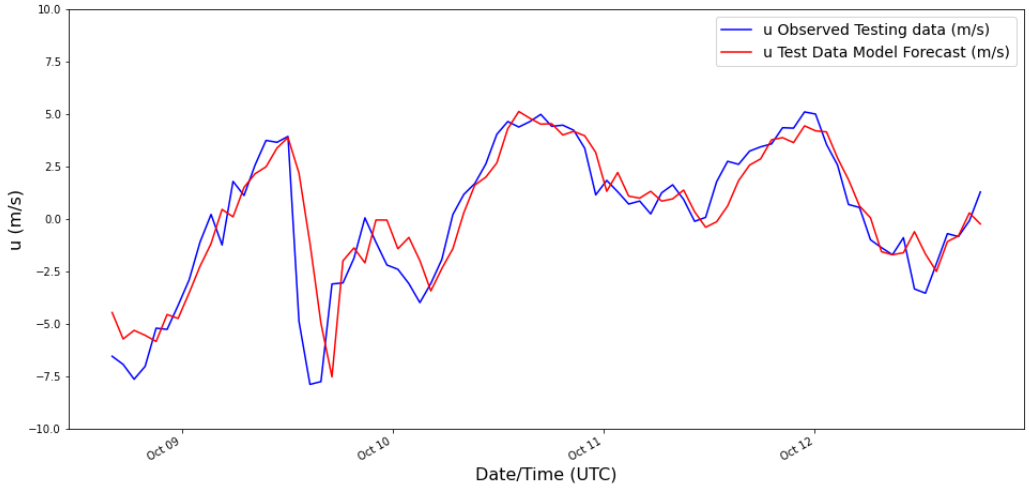

Figure 57. Buoy 21 u LR Case1 prior 3 observed vs. test forecast – No scale factor.

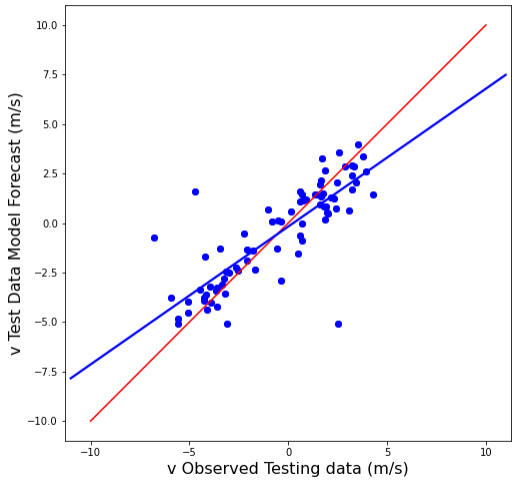

Figure 58. Buoy 21 v LR Case1 prior 3 Test Data – No scale factor, Red line 1-to-1 linear relationship, Blue line best line fit.

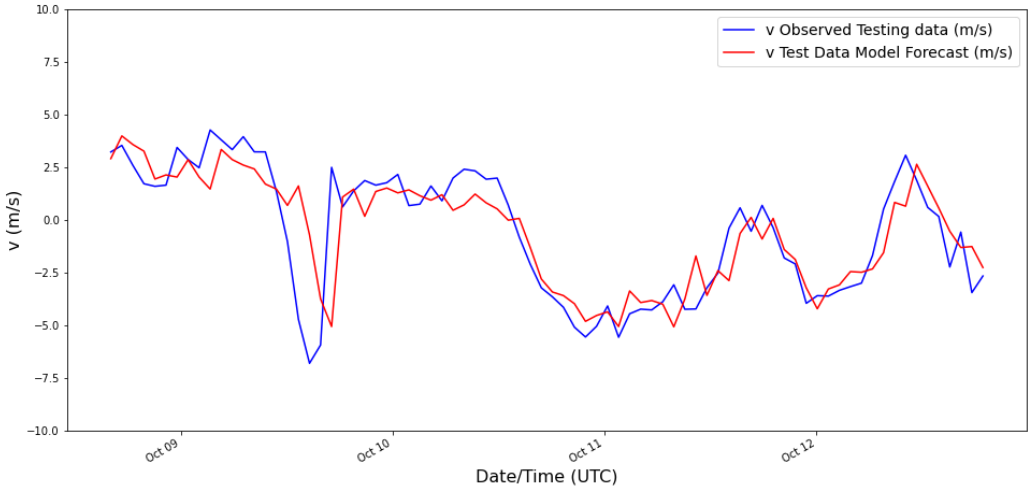

Figure 59. Buoy 21 v LR Case1 prior 3 Observed vs. Test forecast– No scale factor.

Table 24. Metrics for LR Case1 prior 3 Test Data forecast – No scale factor. Adapted from CASPER West data.

Air Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	0.371
Mean Squared Error (MSE)	0.408
Root Mean Squared Error (RMSE)	0.639
Mean Absolute Percentage Error (MAPE)	0.019
Water Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	0.119
Mean Squared Error (MSE)	0.029
Root Mean Squared Error (RMSE)	0.169
Mean Absolute Percentage Error (MAPE)	0.006
Sea Level Pressure Test forecast model error (hPa)	
Mean Absolute Error (MAE)	0.316
Mean Squared Error (MSE)	0.165
Root Mean Squared Error (RMSE)	0.407
Mean Absolute Percentage Error (MAPE)	0.000
Relative Humidity Test forecast model error (%)	
Mean Absolute Error (MAE)	2.922
Mean Squared Error (MSE)	32.310
Root Mean Squared Error (RMSE)	5.684
Mean Absolute Percentage Error (MAPE)	0.051
u Test forecast model error (m/s)	
Mean Absolute Error (MAE)	1.091
Mean Squared Error (MSE)	2.679
Root Mean Squared Error (RMSE)	1.637
Mean Absolute Percentage Error (MAPE)	1.310
v Test forecast model error (m/s)	
Mean Absolute Error (MAE)	1.098
Mean Squared Error (MSE)	2.856
Root Mean Squared Error (RMSE)	1.690
Mean Absolute Percentage Error (MAPE)	0.663

MSE values are squared units.

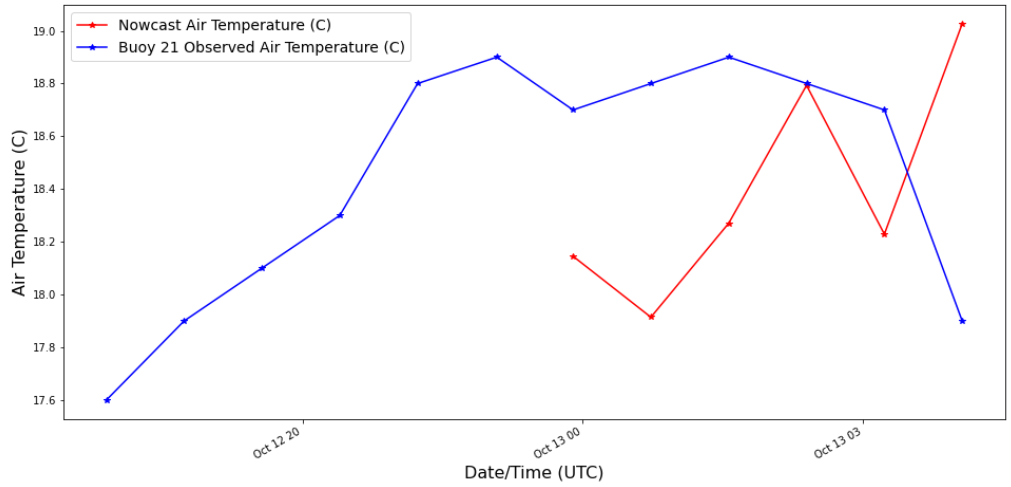

Figure 60. Buoy 21 air temperature LR Case1 prior 3 6-hr nowcast – No scale factor.

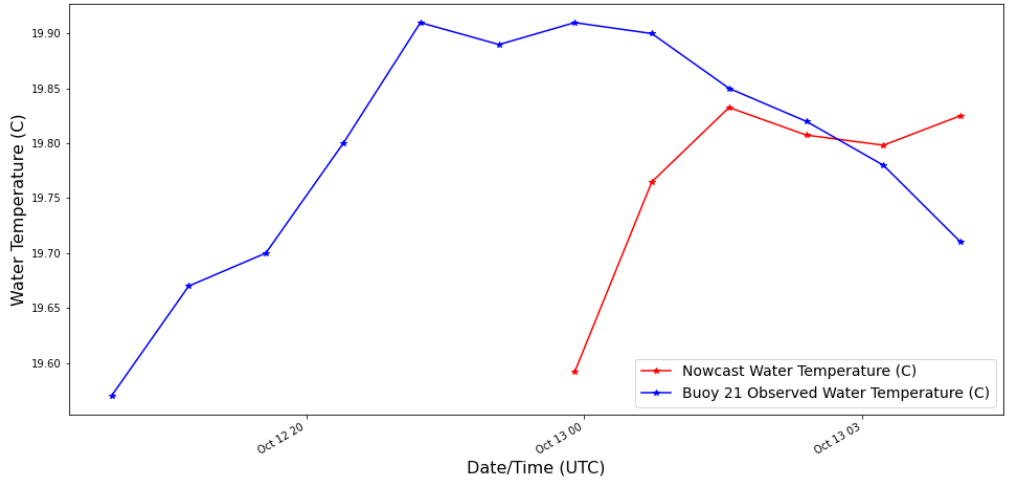

Figure 61. Buoy 21 water temperature LR Case1 prior 3 6-hr nowcast – No scale factor.

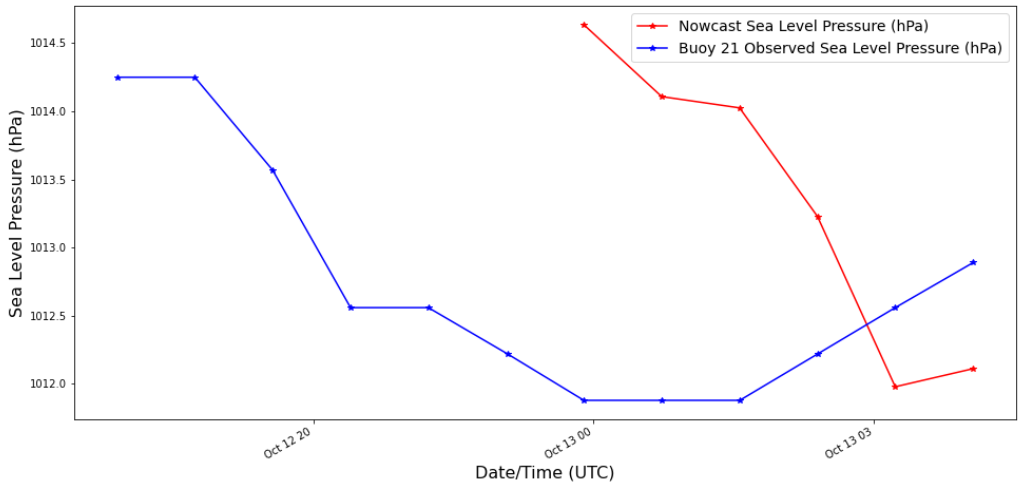

Figure 62. Buoy 21 sea level pressure LR Case1 prior 3 6-hr nowcast – No scale factor.

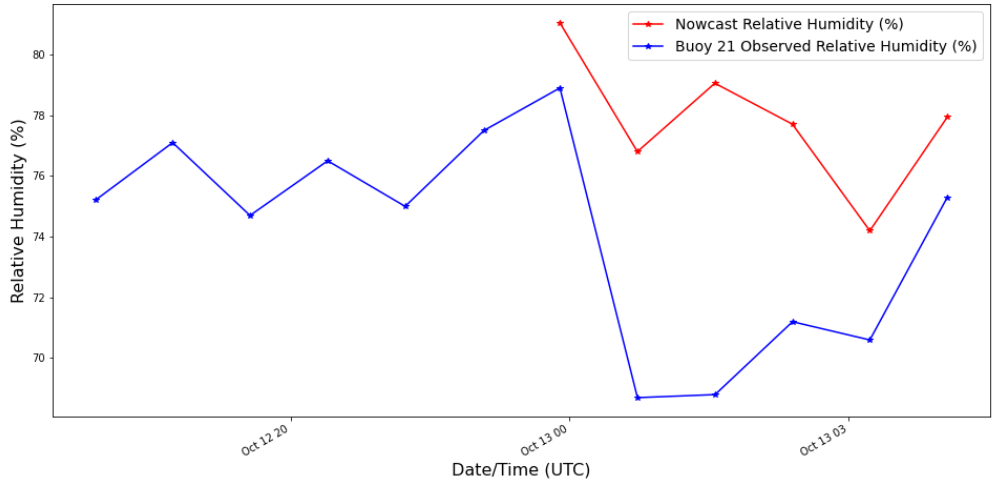

Figure 63. Buoy 21 relative humidity LR Case1 prior 3 6-hr nowcast – No scale factor.

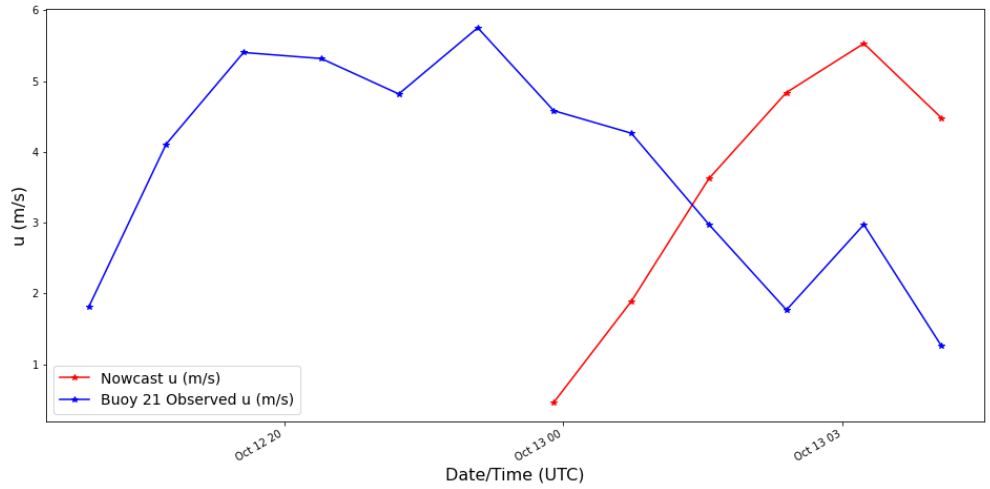

Figure 64. Buoy 21 u LR Case1 prior 3 6-hr nowcast – No scale factor.

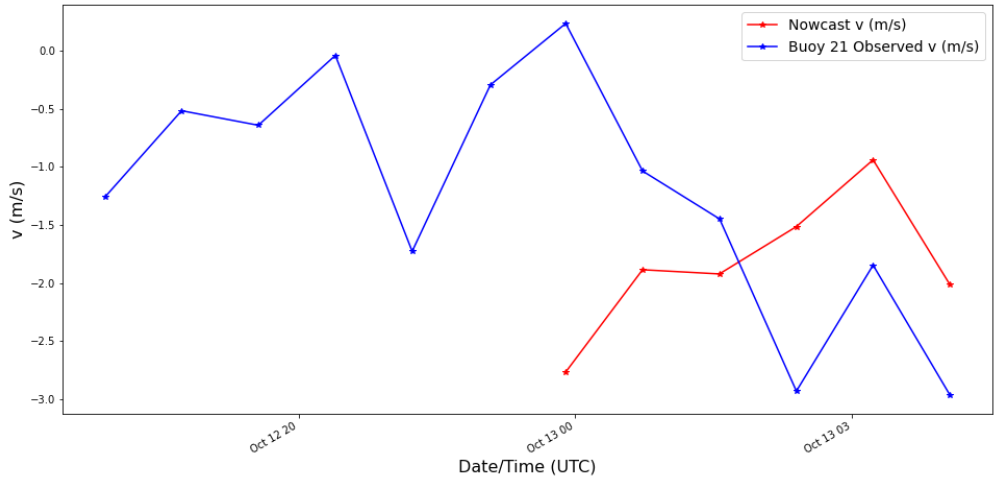

Figure 65. Buoy 21 v LR Case1 prior 3 6-hr nowcast – No scale factor.

Table 25. Metrics for Buoy 21 LR Case1 prior 3 6-hr nowcast no scale. Adapted from CASPER West data.

Air Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	0.612
Mean Squared Error (MSE)	0.496
Root Mean Squared Error (RMSE)	0.705
Mean Absolute Percentage Error (MAPE)	0.033
Water Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	0.103
Mean Squared Error (MSE)	0.022
Root Mean Squared Error (RMSE)	0.149
Mean Absolute Percentage Error (MAPE)	0.005
Sea Level Pressure 6hr forecast model error (hPa)	
Mean Absolute Error (MAE)	1.583
Mean Squared Error (MSE)	3.186
Root Mean Squared Error (RMSE)	1.785
Mean Absolute Percentage Error (MAPE)	0.002
Relative Humidity 6hr forecast model error (%)	
Mean Absolute Error (MAE)	5.541
Mean Squared Error (MSE)	39.609
Root Mean Squared Error (RMSE)	6.294
Mean Absolute Percentage Error (MAPE)	0.079
u 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	2.667
Mean Squared Error (MSE)	8.244
Root Mean Squared Error (RMSE)	2.871
Mean Absolute Percentage Error (MAPE)	1.139
v 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.267
Mean Squared Error (MSE)	2.282
Root Mean Squared Error (RMSE)	1.511
Mean Absolute Percentage Error (MAPE)	2.526

MSE values are squared units.

Table 26. Buoy 21 LR Case1 prior 3 6-hr nowcast no scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-12 23:52:32	18.145396	19.591636	1014.635089	81.043482	0.457394	-2.766016
2017-10-13 00:52:32	17.914471	19.764923	1014.107891	76.802036	1.885818	-1.884934
2017-10-13 01:52:32	18.270592	19.832666	1014.025331	79.054483	3.619468	-1.920997
2017-10-13 02:52:32	18.792996	19.807519	1013.229706	77.708407	4.837948	-1.514150
2017-10-13 03:52:32	18.229187	19.798312	1011.979606	74.196362	5.531596	-0.938593
2017-10-13 04:52:32	19.026423	19.825241	1012.112119	77.940283	4.480926	-2.013209

B. LINEAR REGRESSION

1. BUOY21 Case 1 LR No Scale/Scale Factor, with prior 3 hours comparison

Table 27. Metrics for Buoy 21 LR Case1 prior 3 test data forecast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

CASE1 NO SCALE PRIOR3			CASE1 SCALE PRIOR3	
Air Temperature Test forecast model error (C)			Air Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	0.371		Mean Absolute Error (MAE)	0.371
Mean Squared Error (MSE)	0.408		Mean Squared Error (MSE)	0.408
Root Mean Squared Error (RMSE)	0.639		Root Mean Squared Error (RMSE)	0.639
Mean Absolute Percentage Error (MAPE)	0.019		Mean Absolute Percentage Error (MAPE)	0.019
Water Temperature Test forecast model error (C)			Water Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	0.119		Mean Absolute Error (MAE)	0.119
Mean Squared Error (MSE)	0.029		Mean Squared Error (MSE)	0.029
Root Mean Squared Error (RMSE)	0.169		Root Mean Squared Error (RMSE)	0.169
Mean Absolute Percentage Error (MAPE)	0.006		Mean Absolute Percentage Error (MAPE)	0.006
Sea Level Pressure Test forecast model error (hPa)			Sea Level Pressure Test forecast model error (hPa)	
Mean Absolute Error (MAE)	0.316		Mean Absolute Error (MAE)	0.316
Mean Squared Error (MSE)	0.165		Mean Squared Error (MSE)	0.165
Root Mean Squared Error (RMSE)	0.407		Root Mean Squared Error (RMSE)	0.407
Mean Absolute Percentage Error (MAPE)	0.0		Mean Absolute Percentage Error (MAPE)	0.0
Relative Humidity Test forecast model error (%)			Relative Humidity Test forecast model error (%)	
Mean Absolute Error (MAE)	2.922		Mean Absolute Error (MAE)	2.922
Mean Squared Error (MSE)	32.31		Mean Squared Error (MSE)	32.31
Root Mean Squared Error (RMSE)	5.684		Root Mean Squared Error (RMSE)	5.684
Mean Absolute Percentage Error (MAPE)	0.051		Mean Absolute Percentage Error (MAPE)	0.051
u Test forecast model error (m s^{-1})			u Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.091		Mean Absolute Error (MAE)	1.091
Mean Squared Error (MSE)	2.679		Mean Squared Error (MSE)	2.679
Root Mean Squared Error (RMSE)	1.637		Root Mean Squared Error (RMSE)	1.637
Mean Absolute Percentage Error (MAPE)	1.310		Mean Absolute Percentage Error (MAPE)	1.310
v Test forecast model error (m s^{-1})			v Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.098		Mean Absolute Error (MAE)	1.098
Mean Squared Error (MSE)	2.856		Mean Squared Error (MSE)	2.856
Root Mean Squared Error (RMSE)	1.690		Root Mean Squared Error (RMSE)	1.690
Mean Absolute Percentage Error (MAPE)	0.663		Mean Absolute Percentage Error (MAPE)	0.663

MSE values are squared units.

Table 28. Metrics for Buoy 21 LR Case1 prior 3 6-hr nowcast no scale (left panel), Scale (right panel). Adapted from CASPER West data.

NOWCAST CASE1 NO SCALE PRIOR3			NOWCAST CASE1 SCALE PRIOR3	
Air Temperature 6hr forecast model error (C)			Air Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	0.612		Mean Absolute Error (MAE)	1.056
Mean Squared Error (MSE)	0.496		Mean Squared Error (MSE)	1.629
Root Mean Squared Error (RMSE)	0.705		Root Mean Squared Error (RMSE)	1.276
Mean Absolute Percentage Error (MAPE)	0.033		Mean Absolute Percentage Error (MAPE)	0.057
Water Temperature 6hr forecast model error (C)			Water Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	0.103		Mean Absolute Error (MAE)	0.620
Mean Squared Error (MSE)	0.022		Mean Squared Error (MSE)	0.627
Root Mean Squared Error (RMSE)	0.149		Root Mean Squared Error (RMSE)	0.792
Mean Absolute Percentage Error (MAPE)	0.005		Mean Absolute Percentage Error (MAPE)	0.031
Sea Level Pressure 6hr forecast model error (hPa)			Sea Level Pressure 6hr forecast model error (hPa)	
Mean Absolute Error (MAE)	1.583		Mean Absolute Error (MAE)	2.904
Mean Squared Error (MSE)	3.186		Mean Squared Error (MSE)	14.044
Root Mean Squared Error (RMSE)	1.785		Root Mean Squared Error (RMSE)	3.748
Mean Absolute Percentage Error (MAPE)	0.002		Mean Absolute Percentage Error (MAPE)	0.003
Relative Humidity 6hr forecast model error (%)			Relative Humidity 6hr forecast model error (%)	
Mean Absolute Error (MAE)	5.541		Mean Absolute Error (MAE)	7.607
Mean Squared Error (MSE)	39.609		Mean Squared Error (MSE)	94.496
Root Mean Squared Error (RMSE)	6.294		Root Mean Squared Error (RMSE)	9.721
Mean Absolute Percentage Error (MAPE)	0.079		Mean Absolute Percentage Error (MAPE)	0.105
u 6hr forecast model error ($m\ s^{-1}$)			u 6hr forecast model error ($m\ s^{-1}$)	
Mean Absolute Error (MAE)	2.667		Mean Absolute Error (MAE)	4.057
Mean Squared Error (MSE)	8.244		Mean Squared Error (MSE)	28.983
Root Mean Squared Error (RMSE)	2.871		Root Mean Squared Error (RMSE)	5.384
Mean Absolute Percentage Error (MAPE)	1.139		Mean Absolute Percentage Error (MAPE)	1.178
v 6hr forecast model error ($m\ s^{-1}$)			v 6hr forecast model error ($m\ s^{-1}$)	
Mean Absolute Error (MAE)	1.267		Mean Absolute Error (MAE)	2.399
Mean Squared Error (MSE)	2.282		Mean Squared Error (MSE)	7.863
Root Mean Squared Error (RMSE)	1.511		Root Mean Squared Error (RMSE)	2.804
Mean Absolute Percentage Error (MAPE)	2.526		Mean Absolute Percentage Error (MAPE)	4.149

MSE values are squared units.

Table 29. Buoy 21 LR Case1 prior 3 6-hr nowcast no scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-12 23:52:32	18.145396	19.591636	1014.635089	81.043482	0.457394	-2.766016
2017-10-13 00:52:32	17.914471	19.764923	1014.107891	76.802036	1.885818	-1.884934
2017-10-13 01:52:32	18.270592	19.832666	1014.025331	79.054483	3.619468	-1.920997
2017-10-13 02:52:32	18.792996	19.807519	1013.229706	77.708407	4.837948	-1.514150
2017-10-13 03:52:32	18.229187	19.798312	1011.979606	74.196362	5.531596	-0.938593
2017-10-13 04:52:32	19.026423	19.825241	1012.112119	77.940283	4.480926	-2.013209

Table 30. Buoy 21 LR Case1 prior 3 6-hr nowcast scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-12 23:52:32	18.374079	18.337503	1014.360447	95.871004	-6.570436	-4.593918
2017-10-13 00:52:32	17.136192	19.074993	1012.146764	73.265128	-1.525415	-0.184589
2017-10-13 01:52:32	18.489631	19.650007	1012.155348	83.682820	1.034303	-1.973634
2017-10-13 02:52:32	19.720098	19.590591	1009.823990	73.761611	3.220069	0.359694
2017-10-13 03:52:32	18.007822	19.978190	1006.288815	65.285172	5.994629	0.506941
2017-10-13 04:52:32	20.225481	20.402029	1007.154572	76.646277	2.241982	-0.416443

2. BUOY21 Case 2 LR No Scale/Scale Factor, with prior 3 hours comparison

Table 31. Metrics for Buoy 21 LR Case2 prior 3 test data forecast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

CASE2 No Scale Prior 3			CASE2 SCALE Prior3	
Air Temperature Test forecast model error (C)			Air Temperature Test forecast model error	
Mean Absolute Error (MAE)	0.436		Mean Absolute Error (MAE)	0.436
Mean Squared Error (MSE)	0.358		Mean Squared Error (MSE)	0.358
Root Mean Squared Error (RMSE)	0.598		Root Mean Squared Error (RMSE)	0.598
Mean Absolute Percentage Error (MAPE)	0.022		Mean Absolute Percentage Error (MAPE)	0.022
Water Temperature Test forecast model error			Water Temperature Test forecast model error	
Mean Absolute Error (MAE)	0.095		Mean Absolute Error (MAE)	0.095
Mean Squared Error (MSE)	0.018		Mean Squared Error (MSE)	0.018
Root Mean Squared Error (RMSE)	0.134		Root Mean Squared Error (RMSE)	0.134
Mean Absolute Percentage Error (MAPE)	0.005		Mean Absolute Percentage Error (MAPE)	0.005
Sea Level Pressure Test forecast model error			Sea Level Pressure Test forecast model error	
Mean Absolute Error (MAE)	0.324		Mean Absolute Error (MAE)	0.324
Mean Squared Error (MSE)	0.166		Mean Squared Error (MSE)	0.166
Root Mean Squared Error (RMSE)	0.407		Root Mean Squared Error (RMSE)	0.407
Mean Absolute Percentage Error (MAPE)	0.000		Mean Absolute Percentage Error (MAPE)	0.000
Relative Humidity Test forecast model error			Relative Humidity Test forecast model error	
Mean Absolute Error (MAE)	4.001		Mean Absolute Error (MAE)	4.001
Mean Squared Error (MSE)	36.391		Mean Squared Error (MSE)	36.391
Root Mean Squared Error (RMSE)	6.032		Root Mean Squared Error (RMSE)	6.032
Mean Absolute Percentage Error (MAPE)	0.059		Mean Absolute Percentage Error (MAPE)	0.059
u Test forecast model error			u Test forecast model error	
Mean Absolute Error (MAE)	1.488		Mean Absolute Error (MAE)	1.488
Mean Squared Error (MSE)	4.138		Mean Squared Error (MSE)	4.138
Root Mean Squared Error (RMSE)	2.034		Root Mean Squared Error (RMSE)	2.034
Mean Absolute Percentage Error (MAPE)	0.847		Mean Absolute Percentage Error (MAPE)	0.847
v Test forecast model error			v Test forecast model error	
Mean Absolute Error (MAE)	1.168		Mean Absolute Error (MAE)	1.168
Mean Squared Error (MSE)	2.132		Mean Squared Error (MSE)	2.132
Root Mean Squared Error (RMSE)	1.460		Root Mean Squared Error (RMSE)	1.460
Mean Absolute Percentage Error (MAPE)	0.746		Mean Absolute Percentage Error (MAPE)	0.746

MSE values are squared units.

Table 32. Metrics for Buoy 21 LR Case2 prior 3 6-hr nowcast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

Nowcast CASE2 No Scale Prior3	
Air Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	2.105
Mean Squared Error (MSE)	4.655
Root Mean Squared Error (RMSE)	2.158
Mean Absolute Percentage Error (MAPE)	0.137
Water Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	1.108
Mean Squared Error (MSE)	1.537
Root Mean Squared Error (RMSE)	1.24
Mean Absolute Percentage Error (MAPE)	0.074
Sea Level Pressure Test forecast model error (hPa)	
Mean Absolute Error (MAE)	3.213
Mean Squared Error (MSE)	10.612
Root Mean Squared Error (RMSE)	3.258
Mean Absolute Percentage Error (MAPE)	0.003
Relative Humidity Test forecast model error (%)	
Mean Absolute Error (MAE)	4.664
Mean Squared Error (MSE)	30.32
Root Mean Squared Error (RMSE)	5.506
Mean Absolute Percentage Error (MAPE)	0.063
u Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	4.372
Mean Squared Error (MSE)	21.936
Root Mean Squared Error (RMSE)	4.684
Mean Absolute Percentage Error (MAPE)	27.136
v Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.231
Mean Squared Error (MSE)	2.944
Root Mean Squared Error (RMSE)	1.716
Mean Absolute Percentage Error (MAPE)	0.354

Nowcast CASE2 SCALE Prior3	
Air Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	3.229
Mean Squared Error (MSE)	12.007
Root Mean Squared Error (RMSE)	3.465
Mean Absolute Percentage Error (MAPE)	0.206
Water Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	4.546
Mean Squared Error (MSE)	21.394
Root Mean Squared Error (RMSE)	4.625
Mean Absolute Percentage Error (MAPE)	0.305
Sea Level Pressure Test forecast model error (hPa)	
Mean Absolute Error (MAE)	3.752
Mean Squared Error (MSE)	17.796
Root Mean Squared Error (RMSE)	4.219
Mean Absolute Percentage Error (MAPE)	0.004
Relative Humidity Test forecast model error (%)	
Mean Absolute Error (MAE)	9.153
Mean Squared Error (MSE)	94.213
Root Mean Squared Error (RMSE)	9.706
Mean Absolute Percentage Error (MAPE)	0.123
u Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	2.368
Mean Squared Error (MSE)	7.842
Root Mean Squared Error (RMSE)	2.8
Mean Absolute Percentage Error (MAPE)	9.041
v Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	2.662
Mean Squared Error (MSE)	8.654
Root Mean Squared Error (RMSE)	2.942
Mean Absolute Percentage Error (MAPE)	0.655

MSE values are squared units.

Table 33. Buoy 21 LR Case2 prior 3 6-hr nowcast no scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-21 05:52:48	17.952272	16.651933	1010.399334	75.329306	8.359045	-4.166427
2017-10-21 06:52:48	18.315935	16.395336	1010.642245	77.770192	8.390379	-5.096464
2017-10-21 07:52:48	17.923660	16.267398	1010.665886	73.253063	8.575962	-3.745193
2017-10-21 08:52:48	17.438949	15.982069	1011.044662	70.790031	7.080526	-5.145113
2017-10-21 09:52:48	17.520056	15.622854	1012.414991	72.297892	6.381592	-6.501915
2017-10-21 10:52:48	16.877094	15.330087	1012.412942	73.722851	5.035318	-5.849116

Table 34. Buoy 21 LR Case2 prior 3 6-hr nowcast scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-21 05:52:48	19.824851	20.468182	1007.634518	84.835620	5.721037	-1.428790
2017-10-21 06:52:48	20.641270	20.123200	1009.114570	89.805715	4.155824	-2.147956
2017-10-21 07:52:48	19.955629	19.858638	1009.145471	79.888086	3.645987	-0.011424
2017-10-21 08:52:48	18.675869	19.305937	1010.874419	70.069606	-0.499789	-1.997041
2017-10-21 09:52:48	18.501562	18.798353	1016.257549	70.531825	-2.053695	-2.541562
2017-10-21 10:52:48	15.176714	18.323438	1015.882711	71.487372	-3.786362	0.233214

3. BUOY21 Case 3 LR No Scale/Scale Factor, with prior 3 hours comparison

Table 35. Metrics for Buoy 21 LR Case3 prior 3 test data forecast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

CASE3 No Scale Prior 3		CASE3 SCALE Prior 3	
Air Temperature Test forecast model error (C)		Air Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	0.871	Mean Absolute Error (MAE)	0.871
Mean Squared Error (MSE)	1.937	Mean Squared Error (MSE)	1.937
Root Mean Squared Error (RMSE)	1.392	Root Mean Squared Error (RMSE)	1.392
Mean Absolute Percentage Error (MAPE)	0.038	Mean Absolute Percentage Error (MAPE)	0.038
Water Temperature Test forecast model error (C)		Water Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	0.221	Mean Absolute Error (MAE)	0.221
Mean Squared Error (MSE)	0.073	Mean Squared Error (MSE)	0.073
Root Mean Squared Error (RMSE)	0.271	Root Mean Squared Error (RMSE)	0.271
Mean Absolute Percentage Error (MAPE)	0.013	Mean Absolute Percentage Error (MAPE)	0.013
Sea Level Pressure Test forecast model error (hPa)		Sea Level Pressure Test forecast model error (hPa)	
Mean Absolute Error (MAE)	0.424	Mean Absolute Error (MAE)	0.424
Mean Squared Error (MSE)	0.482	Mean Squared Error (MSE)	0.482
Root Mean Squared Error (RMSE)	0.694	Root Mean Squared Error (RMSE)	0.694
Mean Absolute Percentage Error (MAPE)	0.000	Mean Absolute Percentage Error (MAPE)	0.000
Relative Humidity Test forecast model error (%)		Relative Humidity Test forecast model error (%)	
Mean Absolute Error (MAE)	4.817	Mean Absolute Error (MAE)	4.817
Mean Squared Error (MSE)	44.173	Mean Squared Error (MSE)	44.173
Root Mean Squared Error (RMSE)	6.646	Root Mean Squared Error (RMSE)	6.646
Mean Absolute Percentage Error (MAPE)	0.122	Mean Absolute Percentage Error (MAPE)	0.122
u Test forecast model error (m s^{-1})		u Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	2.127	Mean Absolute Error (MAE)	2.127
Mean Squared Error (MSE)	7.405	Mean Squared Error (MSE)	7.405
Root Mean Squared Error (RMSE)	2.721	Root Mean Squared Error (RMSE)	2.721
Mean Absolute Percentage Error (MAPE)	1.567	Mean Absolute Percentage Error (MAPE)	1.567
v Test forecast model error (m s^{-1})		v Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.947	Mean Absolute Error (MAE)	1.947
Mean Squared Error (MSE)	6.430	Mean Squared Error (MSE)	6.430
Root Mean Squared Error (RMSE)	2.536	Root Mean Squared Error (RMSE)	2.536
Mean Absolute Percentage Error (MAPE)	0.985	Mean Absolute Percentage Error (MAPE)	0.985

MSE values are squared units.

Table 36. Metrics for Buoy 21 LR Case3 prior 3 6-hr nowcast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

Nowcast CASE3 No Scale Prior3		Nowcast CASE3 SCALE Prior3	
Air Temperature 6hr forecast model error (C)		Air Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	1.654	Mean Absolute Error (MAE)	2.605
Mean Squared Error (MSE)	2.939	Mean Squared Error (MSE)	8.575
Root Mean Squared Error (RMSE)	1.714	Root Mean Squared Error (RMSE)	2.928
Mean Absolute Percentage Error (MAPE)	0.079	Mean Absolute Percentage Error (MAPE)	0.125
Water Temperature 6hr forecast model error (C)		Water Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	1.058	Mean Absolute Error (MAE)	1.263
Mean Squared Error (MSE)	1.471	Mean Squared Error (MSE)	3.05
Root Mean Squared Error (RMSE)	1.213	Root Mean Squared Error (RMSE)	1.746
Mean Absolute Percentage Error (MAPE)	0.054	Mean Absolute Percentage Error (MAPE)	0.064
Sea Level Pressure 6hr forecast model error (hPa)		Sea Level Pressure 6hr forecast model error (hPa)	
Mean Absolute Error (MAE)	0.355	Mean Absolute Error (MAE)	2.925
Mean Squared Error (MSE)	0.162	Mean Squared Error (MSE)	15.322
Root Mean Squared Error (RMSE)	0.402	Root Mean Squared Error (RMSE)	3.914
Mean Absolute Percentage Error (MAPE)	0	Mean Absolute Percentage Error (MAPE)	0.003
Relative Humidity 6hr forecast model error (%)		Relative Humidity 6hr forecast model error (%)	
Mean Absolute Error (MAE)	7.655	Mean Absolute Error (MAE)	17.355
Mean Squared Error (MSE)	71.378	Mean Squared Error (MSE)	405.674
Root Mean Squared Error (RMSE)	8.449	Root Mean Squared Error (RMSE)	20.141
Mean Absolute Percentage Error (MAPE)	0.129	Mean Absolute Percentage Error (MAPE)	0.303
u 6hr forecast model error (m s^{-1})		u 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.576	Mean Absolute Error (MAE)	2.886
Mean Squared Error (MSE)	6.022	Mean Squared Error (MSE)	12.495
Root Mean Squared Error (RMSE)	2.454	Root Mean Squared Error (RMSE)	3.535
Mean Absolute Percentage Error (MAPE)	0.827	Mean Absolute Percentage Error (MAPE)	2.885
v 6hr forecast model error (m s^{-1})		v 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	2.744	Mean Absolute Error (MAE)	4.145
Mean Squared Error (MSE)	9.569	Mean Squared Error (MSE)	22.101
Root Mean Squared Error (RMSE)	3.093	Root Mean Squared Error (RMSE)	4.701
Mean Absolute Percentage Error (MAPE)	0.921	Mean Absolute Percentage Error (MAPE)	1.454

MSE values are squared units.

Table 37. Buoy 21 LR Case3 prior 3 6-hr nowcast no scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-26 03:52:45	24.089409	20.980284	1009.716650	68.890770	0.508461	-0.374620
2017-10-26 04:52:45	23.296804	20.999089	1008.984698	58.874759	2.801503	0.143318
2017-10-26 05:52:45	22.755925	21.823185	1009.162553	68.542421	0.363343	-2.464648
2017-10-26 06:52:45	22.070422	19.562390	1009.296714	61.737612	0.661509	-0.768045
2017-10-26 07:52:45	21.753105	20.188207	1009.510233	63.774251	1.566117	-1.473955
2017-10-26 08:52:45	22.055983	20.688810	1009.073898	62.890026	0.531082	-2.650701

Table 38. Buoy 21 LR Case3 prior 3 6-hr nowcast scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-26 03:52:45	24.835290	19.931833	1017.896599	90.958280	-3.502568	0.082098
2017-10-26 04:52:45	21.465036	19.794901	1011.387318	48.298341	7.246789	4.308510
2017-10-26 05:52:45	18.991686	21.603040	1010.145859	81.189367	-0.992227	-6.189129
2017-10-26 06:52:45	18.109121	16.304973	1012.534505	71.327390	2.118915	-0.221395
2017-10-26 07:52:45	15.997076	17.778928	1011.099251	79.812692	3.348490	-2.166969
2017-10-26 08:52:45	16.742236	19.004116	1009.827095	71.662237	-2.060928	-4.744264

4. BUOY22 Case 1 LR No Scale/Scale Factor, with prior 3 hours comparison

Table 39. Metrics for Buoy 22 LR Case1 prior 3 test data forecast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

CASE1 No Scale Prior 3		CASE1 SCALE Prior 3	
Air Temperature Test forecast model error (C)		Air Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	0.140	Mean Absolute Error (MAE)	0.140
Mean Squared Error (MSE)	0.040	Mean Squared Error (MSE)	0.040
Root Mean Squared Error (RMSE)	0.200	Root Mean Squared Error (RMSE)	0.200
Mean Absolute Percentage Error (MAPE)	0.008	Mean Absolute Percentage Error (MAPE)	0.008
Water Temperature Test forecast model error (C)		Water Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	0.095	Mean Absolute Error (MAE)	0.095
Mean Squared Error (MSE)	0.014	Mean Squared Error (MSE)	0.014
Root Mean Squared Error (RMSE)	0.120	Root Mean Squared Error (RMSE)	0.120
Mean Absolute Percentage Error (MAPE)	0.005	Mean Absolute Percentage Error (MAPE)	0.005
Sea Level Pressure Test forecast model error (hPa)		Sea Level Pressure Test forecast model error (hPa)	
Mean Absolute Error (MAE)	0.201	Mean Absolute Error (MAE)	0.201
Mean Squared Error (MSE)	0.062	Mean Squared Error (MSE)	0.062
Root Mean Squared Error (RMSE)	0.250	Root Mean Squared Error (RMSE)	0.250
Mean Absolute Percentage Error (MAPE)	0.000	Mean Absolute Percentage Error (MAPE)	0.000
Relative Humidity Test forecast model error (%)		Relative Humidity Test forecast model error (%)	
Mean Absolute Error (MAE)	1.508	Mean Absolute Error (MAE)	1.508
Mean Squared Error (MSE)	3.979	Mean Squared Error (MSE)	3.979
Root Mean Squared Error (RMSE)	1.995	Root Mean Squared Error (RMSE)	1.995
Mean Absolute Percentage Error (MAPE)	0.019	Mean Absolute Percentage Error (MAPE)	0.019
u Test forecast model error (m s^{-1})		u Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	0.672	Mean Absolute Error (MAE)	0.672
Mean Squared Error (MSE)	0.844	Mean Squared Error (MSE)	0.844
Root Mean Squared Error (RMSE)	0.919	Root Mean Squared Error (RMSE)	0.919
Mean Absolute Percentage Error (MAPE)	0.799	Mean Absolute Percentage Error (MAPE)	0.799
v Test forecast model error (m s^{-1})		v Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	0.564	Mean Absolute Error (MAE)	0.564
Mean Squared Error (MSE)	0.530	Mean Squared Error (MSE)	0.530
Root Mean Squared Error (RMSE)	0.728	Root Mean Squared Error (RMSE)	0.728
Mean Absolute Percentage Error (MAPE)	0.872	Mean Absolute Percentage Error (MAPE)	0.872

MSE values are squared units.

Table 40. Metrics for Buoy 22 LR Case1 prior 3 6-hr nowcast no scale (left panel), Scale (right panel). Adapted from CASPER West data.

Nowcast CASE1 No Scale Prior3		Nowcast CASE1 SCALE Prior3	
Air Temperature 6hr forecast model error (C)		Air Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	0.290	Mean Absolute Error (MAE)	0.789
Mean Squared Error (MSE)	0.095	Mean Squared Error (MSE)	2.464
Root Mean Squared Error (RMSE)	0.308	Root Mean Squared Error (RMSE)	1.570
Mean Absolute Percentage Error (MAPE)	0.016	Mean Absolute Percentage Error (MAPE)	0.043
Water Temperature 6hr forecast model error (C)		Water Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	0.153	Mean Absolute Error (MAE)	0.972
Mean Squared Error (MSE)	0.028	Mean Squared Error (MSE)	1.169
Root Mean Squared Error (RMSE)	0.166	Root Mean Squared Error (RMSE)	1.081
Mean Absolute Percentage Error (MAPE)	0.008	Mean Absolute Percentage Error (MAPE)	0.050
Sea Level Pressure 6hr forecast model error (hPa)		Sea Level Pressure 6hr forecast model error (hPa)	
Mean Absolute Error (MAE)	1.459	Mean Absolute Error (MAE)	2.775
Mean Squared Error (MSE)	3.163	Mean Squared Error (MSE)	10.958
Root Mean Squared Error (RMSE)	1.778	Root Mean Squared Error (RMSE)	3.310
Mean Absolute Percentage Error (MAPE)	0.001	Mean Absolute Percentage Error (MAPE)	0.003
Relative Humidity 6hr forecast model error (%)		Relative Humidity 6hr forecast model error (%)	
Mean Absolute Error (MAE)	3.967	Mean Absolute Error (MAE)	3.853
Mean Squared Error (MSE)	21.964	Mean Squared Error (MSE)	21.981
Root Mean Squared Error (RMSE)	4.687	Root Mean Squared Error (RMSE)	4.688
Mean Absolute Percentage Error (MAPE)	0.050	Mean Absolute Percentage Error (MAPE)	0.051
u 6hr forecast model error (m s^{-1})		u 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	3.061	Mean Absolute Error (MAE)	3.501
Mean Squared Error (MSE)	10.763	Mean Squared Error (MSE)	27.863
Root Mean Squared Error (RMSE)	3.281	Root Mean Squared Error (RMSE)	5.279
Mean Absolute Percentage Error (MAPE)	1.660	Mean Absolute Percentage Error (MAPE)	1.019
v 6hr forecast model error (m s^{-1})		v 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	0.482	Mean Absolute Error (MAE)	1.792
Mean Squared Error (MSE)	0.310	Mean Squared Error (MSE)	4.178
Root Mean Squared Error (RMSE)	0.556	Root Mean Squared Error (RMSE)	2.044
Mean Absolute Percentage Error (MAPE)	0.741	Mean Absolute Percentage Error (MAPE)	3.142

MSE values are squared units.

Table 41. Buoy 22 LR Case1 prior 3 6-hr nowcast no scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-13 00:00:00	18.523714	19.483379	1015.245385	73.727295	1.415073	-0.260875
2017-10-13 01:00:00	18.052966	19.626195	1014.587623	74.048904	3.343677	-0.235577
2017-10-13 02:00:00	18.093914	19.527379	1014.194609	75.706808	5.145602	-0.268575
2017-10-13 03:00:00	18.019255	19.573565	1013.186025	76.707625	5.501368	-0.619003
2017-10-13 04:00:00	18.085474	19.544288	1012.538407	79.285025	5.516842	-0.742916
2017-10-13 05:00:00	18.017618	19.533503	1012.684929	79.721037	5.025755	-0.221743

Table 42. Buoy 22 LR Case1 prior 3 6-hr nowcast scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-13 00:00:00	22.083080	18.665277	1014.243461	80.498130	-5.137002	-0.957471
2017-10-13 01:00:00	17.893516	20.258879	1013.010906	77.756461	-2.511362	1.153379
2017-10-13 02:00:00	18.401880	19.555309	1011.847741	83.296009	3.662558	0.227792
2017-10-13 03:00:00	18.417836	20.332898	1009.097448	79.014623	2.448072	-4.606285
2017-10-13 04:00:00	18.794097	20.894463	1007.767038	82.736989	2.830212	-2.737100
2017-10-13 05:00:00	18.336845	20.897193	1008.657850	74.386134	2.326964	2.245169

5. BUOY22 Case 2 LR No Scale/Scale Factor, with prior 3 hours comparison

Table 43. Metrics for Buoy 22 LR Case2 prior 3 test data forecast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

CASE2 No Scale Prior 3		CASE2 SCALE Prior 3	
Air Temperature Test forecast model error (C)		Air Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	0.197	Mean Absolute Error (MAE)	0.197
Mean Squared Error (MSE)	0.075	Mean Squared Error (MSE)	0.075
Root Mean Squared Error (RMSE)	0.275	Root Mean Squared Error (RMSE)	0.275
Mean Absolute Percentage Error (MAPE)	0.010	Mean Absolute Percentage Error (MAPE)	0.010
Water Temperature Test forecast model error (C)		Water Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	0.071	Mean Absolute Error (MAE)	0.071
Mean Squared Error (MSE)	0.008	Mean Squared Error (MSE)	0.008
Root Mean Squared Error (RMSE)	0.091	Root Mean Squared Error (RMSE)	0.091
Mean Absolute Percentage Error (MAPE)	0.003	Mean Absolute Percentage Error (MAPE)	0.003
Sea Level Pressure Test forecast model error (hPa)		Sea Level Pressure Test forecast model error (hPa)	
Mean Absolute Error (MAE)	0.265	Mean Absolute Error (MAE)	0.265
Mean Squared Error (MSE)	0.112	Mean Squared Error (MSE)	0.112
Root Mean Squared Error (RMSE)	0.334	Root Mean Squared Error (RMSE)	0.334
Mean Absolute Percentage Error (MAPE)	0.000	Mean Absolute Percentage Error (MAPE)	0.000
Relative Humidity Test forecast model error (%)		Relative Humidity Test forecast model error (%)	
Mean Absolute Error (MAE)	2.043	Mean Absolute Error (MAE)	2.043
Mean Squared Error (MSE)	8.149	Mean Squared Error (MSE)	8.149
Root Mean Squared Error (RMSE)	2.855	Root Mean Squared Error (RMSE)	2.855
Mean Absolute Percentage Error (MAPE)	0.028	Mean Absolute Percentage Error (MAPE)	0.028
u Test forecast model error (m s^{-1})		u Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.006	Mean Absolute Error (MAE)	1.006
Mean Squared Error (MSE)	1.926	Mean Squared Error (MSE)	1.926
Root Mean Squared Error (RMSE)	1.388	Root Mean Squared Error (RMSE)	1.388
Mean Absolute Percentage Error (MAPE)	0.414	Mean Absolute Percentage Error (MAPE)	0.414
v Test forecast model error (m s^{-1})		v Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.062	Mean Absolute Error (MAE)	1.062
Mean Squared Error (MSE)	2.758	Mean Squared Error (MSE)	2.758
Root Mean Squared Error (RMSE)	1.661	Root Mean Squared Error (RMSE)	1.661
Mean Absolute Percentage Error (MAPE)	0.876	Mean Absolute Percentage Error (MAPE)	0.876

MSE values are squared units.

Table 44. Metrics for Buoy 22 LR Case2 prior 3 6-hr nowcast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

Nowcast CASE2 No Scale Prior3		Nowcast CASE2 SCALE Prior3	
Air Temperature 6hr forecast model error (C)		Air Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	0.716	Mean Absolute Error (MAE)	2.106
Mean Squared Error (MSE)	0.613	Mean Squared Error (MSE)	5.343
Root Mean Squared Error (RMSE)	0.783	Root Mean Squared Error (RMSE)	2.311
Mean Absolute Percentage Error (MAPE)	0.042	Mean Absolute Percentage Error (MAPE)	0.123
Water Temperature 6hr forecast model error (C)		Water Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	0.830	Mean Absolute Error (MAE)	1.840
Mean Squared Error (MSE)	0.740	Mean Squared Error (MSE)	3.734
Root Mean Squared Error (RMSE)	0.860	Root Mean Squared Error (RMSE)	1.932
Mean Absolute Percentage Error (MAPE)	0.045	Mean Absolute Percentage Error (MAPE)	0.101
Sea Level Pressure 6hr forecast model error (hPa)		Sea Level Pressure 6hr forecast model error (hPa)	
Mean Absolute Error (MAE)	2.542	Mean Absolute Error (MAE)	3.292
Mean Squared Error (MSE)	6.683	Mean Squared Error (MSE)	15.679
Root Mean Squared Error (RMSE)	2.585	Root Mean Squared Error (RMSE)	3.960
Mean Absolute Percentage Error (MAPE)	0.003	Mean Absolute Percentage Error (MAPE)	0.003
Relative Humidity 6hr forecast model error (%)		Relative Humidity 6hr forecast model error (%)	
Mean Absolute Error (MAE)	1.887	Mean Absolute Error (MAE)	10.167
Mean Squared Error (MSE)	6.147	Mean Squared Error (MSE)	145.062
Root Mean Squared Error (RMSE)	2.479	Root Mean Squared Error (RMSE)	12.044
Mean Absolute Percentage Error (MAPE)	0.028	Mean Absolute Percentage Error (MAPE)	0.149
u 6hr forecast model error (m s^{-1})		u 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	4.837	Mean Absolute Error (MAE)	3.837
Mean Squared Error (MSE)	25.203	Mean Squared Error (MSE)	18.545
Root Mean Squared Error (RMSE)	5.020	Root Mean Squared Error (RMSE)	4.306
Mean Absolute Percentage Error (MAPE)	2.119	Mean Absolute Percentage Error (MAPE)	1.430
v 6hr forecast model error (m s^{-1})		v 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.562	Mean Absolute Error (MAE)	3.772
Mean Squared Error (MSE)	4.475	Mean Squared Error (MSE)	19.369
Root Mean Squared Error (RMSE)	2.115	Root Mean Squared Error (RMSE)	4.401
Mean Absolute Percentage Error (MAPE)	0.439	Mean Absolute Percentage Error (MAPE)	0.709

MSE values are squared units.

Table 45. Buoy 22 LR Case2 prior 3 6-hr nowcast no scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-21 06:00:00	18.500396	19.714167	1011.476484	71.008872	10.768922	-5.236660
2017-10-21 07:00:00	18.145259	19.417773	1011.038501	70.088063	11.372720	-6.116034
2017-10-21 08:00:00	17.808304	19.014321	1011.201754	69.673280	11.122910	-6.163313
2017-10-21 09:00:00	17.535164	18.974092	1012.544822	70.749372	9.786722	-5.057027
2017-10-21 10:00:00	17.616189	18.687872	1012.257791	70.915008	8.607303	-7.028191
2017-10-21 11:00:00	17.263130	18.696959	1013.002470	69.337151	8.389426	-6.607956

Table 46. Buoy 22 LR Case2 prior 3 6-hr nowcast scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-21 06:00:00	20.955628	21.340467	1009.761796	77.933063	3.241121	-0.856360
2017-10-21 07:00:00	20.042570	20.697814	1007.712515	70.316332	6.104761	-1.269457
2017-10-21 08:00:00	18.853281	19.831029	1008.771884	73.796630	4.907713	-1.641172
2017-10-21 09:00:00	18.508734	20.076526	1015.440536	87.743288	-0.585935	1.993879
2017-10-21 10:00:00	19.557731	19.301058	1013.322189	87.435343	-2.348899	-2.768226
2017-10-21 11:00:00	17.296024	19.318793	1016.487193	74.684261	-3.314486	-2.297362

6. BUOY22 Case 3 LR No Scale/Scale Factor, with prior 3 hours comparison

Table 47. Metrics for Buoy 22 LR Case3 prior 3 test data forecast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

CASE3 No Scale Prior 3		CASE3 SCALE Prior 3	
Air Temperature Test forecast model error (C)		Air Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	0.364	Mean Absolute Error (MAE)	0.364
Mean Squared Error (MSE)	0.312	Mean Squared Error (MSE)	0.312
Root Mean Squared Error (RMSE)	0.559	Root Mean Squared Error (RMSE)	0.559
Mean Absolute Percentage Error (MAPE)	0.016	Mean Absolute Percentage Error (MAPE)	0.016
Water Temperature Test forecast model error (C)		Water Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	0.115	Mean Absolute Error (MAE)	0.115
Mean Squared Error (MSE)	0.024	Mean Squared Error (MSE)	0.024
Root Mean Squared Error (RMSE)	0.155	Root Mean Squared Error (RMSE)	0.155
Mean Absolute Percentage Error (MAPE)	0.006	Mean Absolute Percentage Error (MAPE)	0.006
Sea Level Pressure Test forecast model error (hPa)		Sea Level Pressure Test forecast model error (hPa)	
Mean Absolute Error (MAE)	0.237	Mean Absolute Error (MAE)	0.237
Mean Squared Error (MSE)	0.100	Mean Squared Error (MSE)	0.100
Root Mean Squared Error (RMSE)	0.316	Root Mean Squared Error (RMSE)	0.316
Mean Absolute Percentage Error (MAPE)	0.000	Mean Absolute Percentage Error (MAPE)	0.000
Relative Humidity Test forecast model error (%)		Relative Humidity Test forecast model error (%)	
Mean Absolute Error (MAE)	3.038	Mean Absolute Error (MAE)	3.038
Mean Squared Error (MSE)	16.838	Mean Squared Error (MSE)	16.838
Root Mean Squared Error (RMSE)	4.103	Root Mean Squared Error (RMSE)	4.103
Mean Absolute Percentage Error (MAPE)	0.059	Mean Absolute Percentage Error (MAPE)	0.059
u Test forecast model error (m s^{-1})		u Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.014	Mean Absolute Error (MAE)	1.014
Mean Squared Error (MSE)	1.939	Mean Squared Error (MSE)	1.939
Root Mean Squared Error (RMSE)	1.392	Root Mean Squared Error (RMSE)	1.392
Mean Absolute Percentage Error (MAPE)	1.340	Mean Absolute Percentage Error (MAPE)	1.340
v Test forecast model error (m s^{-1})		v Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	0.978	Mean Absolute Error (MAE)	0.978
Mean Squared Error (MSE)	2.381	Mean Squared Error (MSE)	2.381
Root Mean Squared Error (RMSE)	1.543	Root Mean Squared Error (RMSE)	1.543
Mean Absolute Percentage Error (MAPE)	0.993	Mean Absolute Percentage Error (MAPE)	0.993

MSE values are squared units.

Table 48. Metrics for Buoy 22 LR Case3 prior 3 6-hr nowcast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

Nowcast CASE3 No Scale Prior3		Nowcast CASE3 SCALE Prior3	
Air Temperature 6hr forecast model error (C)		Air Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	1.970	Mean Absolute Error (MAE)	2.516
Mean Squared Error (MSE)	6.372	Mean Squared Error (MSE)	8.290
Root Mean Squared Error (RMSE)	2.524	Root Mean Squared Error (RMSE)	2.879
Mean Absolute Percentage Error (MAPE)	0.092	Mean Absolute Percentage Error (MAPE)	0.118
Water Temperature 6hr forecast model error (C)		Water Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	1.708	Mean Absolute Error (MAE)	0.890
Mean Squared Error (MSE)	3.386	Mean Squared Error (MSE)	0.954
Root Mean Squared Error (RMSE)	1.840	Root Mean Squared Error (RMSE)	0.977
Mean Absolute Percentage Error (MAPE)	0.086	Mean Absolute Percentage Error (MAPE)	0.045
Sea Level Pressure 6hr forecast model error (hPa)		Sea Level Pressure 6hr forecast model error (hPa)	
Mean Absolute Error (MAE)	0.294	Mean Absolute Error (MAE)	3.096
Mean Squared Error (MSE)	0.128	Mean Squared Error (MSE)	18.031
Root Mean Squared Error (RMSE)	0.358	Root Mean Squared Error (RMSE)	4.246
Mean Absolute Percentage Error (MAPE)	0.000	Mean Absolute Percentage Error (MAPE)	0.003
Relative Humidity 6hr forecast model error (%)		Relative Humidity 6hr forecast model error (%)	
Mean Absolute Error (MAE)	5.699	Mean Absolute Error (MAE)	13.863
Mean Squared Error (MSE)	37.085	Mean Squared Error (MSE)	279.581
Root Mean Squared Error (RMSE)	6.090	Root Mean Squared Error (RMSE)	16.721
Mean Absolute Percentage Error (MAPE)	0.094	Mean Absolute Percentage Error (MAPE)	0.228
u 6hr forecast model error (m s^{-1})		u 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.172	Mean Absolute Error (MAE)	2.938
Mean Squared Error (MSE)	2.037	Mean Squared Error (MSE)	12.208
Root Mean Squared Error (RMSE)	1.427	Root Mean Squared Error (RMSE)	3.494
Mean Absolute Percentage Error (MAPE)	1.060	Mean Absolute Percentage Error (MAPE)	2.579
v 6hr forecast model error (m s^{-1})		v 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.987	Mean Absolute Error (MAE)	2.773
Mean Squared Error (MSE)	5.740	Mean Squared Error (MSE)	10.730
Root Mean Squared Error (RMSE)	2.396	Root Mean Squared Error (RMSE)	3.276
Mean Absolute Percentage Error (MAPE)	1.409	Mean Absolute Percentage Error (MAPE)	1.584

MSE values are squared units.

Table 49. Buoy 22 LR Case 3 prior 3 6-hr nowcast no scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-26 03:00:00	25.525655	22.279576	1009.715105	62.017975	2.379642	0.997370
2017-10-26 04:00:00	25.169268	22.037060	1008.831643	67.393262	3.469943	-1.519888
2017-10-26 05:00:00	23.501030	22.387124	1009.405551	67.659736	2.189119	-2.754390
2017-10-26 06:00:00	22.484031	21.587138	1009.816464	63.941946	0.706754	-2.567957
2017-10-26 07:00:00	22.200539	20.846488	1009.288346	66.832409	1.196223	-3.199260
2017-10-26 08:00:00	21.131562	20.413507	1009.528081	66.815111	1.786998	-2.335518

Table 50. Buoy 22 LR Case3 prior 3 6-hr nowcast scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-26 03:00:00	23.052073	21.268589	1018.634583	72.410993	-3.452093	2.721983
2017-10-26 04:00:00	21.215919	20.588872	1012.536949	60.556263	3.281898	0.187020
2017-10-26 05:00:00	20.255995	20.800098	1011.675488	84.495465	3.680775	-3.594201
2017-10-26 06:00:00	17.945155	20.059220	1012.707000	69.325466	-1.110733	-1.687610
2017-10-26 07:00:00	18.458018	18.983665	1009.247741	86.270142	2.225044	-4.609731
2017-10-26 08:00:00	16.325382	18.360271	1010.491768	80.931332	5.057219	-1.451778

C. DECISION TREES

1. BUOY21 Case 1 DT No Scale/Scale Factor, with prior 3 hours comparison

Table 51. Metrics for Buoy 21 DT Case1 prior 3 test data forecast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

CASE1 NO SCALE PRIOR3		CASE1 SCALE PRIOR3	
Air Temperature Test forecast model error (C)		Air Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	0.756	Mean Absolute Error (MAE)	0.737
Mean Squared Error (MSE)	1.704	Mean Squared Error (MSE)	1.491
Root Mean Squared Error (RMSE)	1.305	Root Mean Squared Error (RMSE)	1.221
Mean Absolute Percentage Error (MAPE)	0.039	Mean Absolute Percentage Error (MAPE)	0.039
Water Temperature Test forecast model error (C)		Water Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	0.228	Mean Absolute Error (MAE)	0.239
Mean Squared Error (MSE)	0.161	Mean Squared Error (MSE)	0.166
Root Mean Squared Error (RMSE)	0.401	Root Mean Squared Error (RMSE)	0.407
Mean Absolute Percentage Error (MAPE)	0.012	Mean Absolute Percentage Error (MAPE)	0.012
Sea Level Pressure Test forecast model error (hPa)		Sea Level Pressure Test forecast model error (hPa)	
Mean Absolute Error (MAE)	0.449	Mean Absolute Error (MAE)	0.526
Mean Squared Error (MSE)	0.351	Mean Squared Error (MSE)	0.483
Root Mean Squared Error (RMSE)	0.592	Root Mean Squared Error (RMSE)	0.695
Mean Absolute Percentage Error (MAPE)	0.000	Mean Absolute Percentage Error (MAPE)	0.001
Relative Humidity Test forecast model error (%)		Relative Humidity Test forecast model error (%)	
Mean Absolute Error (MAE)	5.484	Mean Absolute Error (MAE)	5.006
Mean Squared Error (MSE)	88.418	Mean Squared Error (MSE)	81.486
Root Mean Squared Error (RMSE)	9.403	Root Mean Squared Error (RMSE)	9.027
Mean Absolute Percentage Error (MAPE)	0.105	Mean Absolute Percentage Error (MAPE)	0.098
u Test forecast model error ($m\ s^{-1}$)		u Test forecast model error ($m\ s^{-1}$)	
Mean Absolute Error (MAE)	1.831	Mean Absolute Error (MAE)	1.756
Mean Squared Error (MSE)	7.082	Mean Squared Error (MSE)	6.698
Root Mean Squared Error (RMSE)	2.661	Root Mean Squared Error (RMSE)	2.588
Mean Absolute Percentage Error (MAPE)	1.153	Mean Absolute Percentage Error (MAPE)	1.048
v Test forecast model error ($m\ s^{-1}$)		v Test forecast model error ($m\ s^{-1}$)	
Mean Absolute Error (MAE)	1.508	Mean Absolute Error (MAE)	1.471
Mean Squared Error (MSE)	5.010	Mean Squared Error (MSE)	4.626
Root Mean Squared Error (RMSE)	2.238	Root Mean Squared Error (RMSE)	2.151
Mean Absolute Percentage Error (MAPE)	0.914	Mean Absolute Percentage Error (MAPE)	0.956

MSE values are squared units.

Table 52. Metrics for Buoy 21 DT Case1 prior 3 6-hr nowcast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

NOWCAST CASE1 NO SCALE PRIOR3		NOWCAST CASE1 SCALE PRIOR3	
Air Temperature 6hr forecast model error (C)		Air Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	0.850	Mean Absolute Error (MAE)	1.450
Mean Squared Error (MSE)	1.075	Mean Squared Error (MSE)	3.472
Root Mean Squared Error (RMSE)	1.037	Root Mean Squared Error (RMSE)	1.863
Mean Absolute Percentage Error (MAPE)	0.046	Mean Absolute Percentage Error (MAPE)	0.079
Water Temperature 6hr forecast model error (C)		Water Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	0.283	Mean Absolute Error (MAE)	0.692
Mean Squared Error (MSE)	0.119	Mean Squared Error (MSE)	1.001
Root Mean Squared Error (RMSE)	0.346	Root Mean Squared Error (RMSE)	1.001
Mean Absolute Percentage Error (MAPE)	0.014	Mean Absolute Percentage Error (MAPE)	0.035
Sea Level Pressure 6hr forecast model error (hPa)		Sea Level Pressure 6hr forecast model error (hPa)	
Mean Absolute Error (MAE)	1.635	Mean Absolute Error (MAE)	2.595
Mean Squared Error (MSE)	4.187	Mean Squared Error (MSE)	12.491
Root Mean Squared Error (RMSE)	2.046	Root Mean Squared Error (RMSE)	3.534
Mean Absolute Percentage Error (MAPE)	0.002	Mean Absolute Percentage Error (MAPE)	0.003
Relative Humidity 6hr forecast model error (%)		Relative Humidity 6hr forecast model error(%)	
Mean Absolute Error (MAE)	4.633	Mean Absolute Error (MAE)	5.983
Mean Squared Error (MSE)	28.940	Mean Squared Error (MSE)	67.295
Root Mean Squared Error (RMSE)	5.380	Root Mean Squared Error (RMSE)	8.203
Mean Absolute Percentage Error (MAPE)	0.064	Mean Absolute Percentage Error (MAPE)	0.085
u 6hr forecast model error (m s^{-1})		u 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	3.118	Mean Absolute Error (MAE)	3.281
Mean Squared Error (MSE)	10.450	Mean Squared Error (MSE)	15.322
Root Mean Squared Error (RMSE)	3.233	Root Mean Squared Error (RMSE)	3.914
Mean Absolute Percentage Error (MAPE)	1.318	Mean Absolute Percentage Error (MAPE)	1.266
v 6hr forecast model error (m s^{-1})		v 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.705	Mean Absolute Error (MAE)	1.658
Mean Squared Error (MSE)	4.285	Mean Squared Error (MSE)	3.844
Root Mean Squared Error (RMSE)	2.070	Root Mean Squared Error (RMSE)	1.960
Mean Absolute Percentage Error (MAPE)	3.463	Mean Absolute Percentage Error (MAPE)	1.035

MSE values are squared units.

Table 53. Buoy 21 DT Case1 Prior 1 6-hr nowcast no scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-12 23:52:32	18.3	19.36	1014.93	83.0	0.581104	-3.891932
2017-10-13 00:52:32	17.2	19.71	1014.59	70.2	0.581104	-2.009642
2017-10-13 01:52:32	17.2	19.71	1014.59	73.0	4.632870	-2.009642
2017-10-13 02:52:32	19.2	19.25	1013.23	69.1	5.234779	-1.767921
2017-10-13 03:52:32	18.9	19.62	1012.56	80.3	5.234779	0.215390
2017-10-13 04:52:32	18.7	19.62	1012.56	69.1	4.894054	-1.621146

Table 54. Buoy 21 DT Case1 Prior 1 6-hr nowcast scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-12 23:52:32	16.3	17.83	1012.89	80.3	-0.901515	0.444288
2017-10-13 00:52:32	18.4	18.75	1012.22	70.2	-1.681006	-2.039619
2017-10-13 01:52:32	18.8	19.53	1011.88	84.4	0.554322	1.009960
2017-10-13 02:52:32	17.6	19.87	1009.51	67.6	2.650778	0.035167
2017-10-13 03:52:32	19.8	19.83	1007.14	82.4	2.448096	0.729045
2017-10-13 04:52:32	21.4	20.21	1006.80	73.3	5.685444	-3.705182

2. BUOY21 Case 2 DT No Scale/Scale Factor, with prior 3 hours comparison

Table 55. Metrics for Buoy 21 DT Case2 prior 3 test data forecast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

CASE2 NO SCALE PRIOR3	
Air Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	0.601
Mean Squared Error (MSE)	1.149
Root Mean Squared Error (RMSE)	1.072
Mean Absolute Percentage Error (MAPE)	0.031
Water Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	0.208
Mean Squared Error (MSE)	0.073
Root Mean Squared Error (RMSE)	0.271
Mean Absolute Percentage Error (MAPE)	0.011
Sea Level Pressure Test forecast model error (hPa)	
Mean Absolute Error (MAE)	0.556
Mean Squared Error (MSE)	0.485
Root Mean Squared Error (RMSE)	0.696
Mean Absolute Percentage Error (MAPE)	0.001
Relative Humidity Test forecast model error (%)	
Mean Absolute Error (MAE)	6.289
Mean Squared Error (MSE)	71.484
Root Mean Squared Error (RMSE)	8.455
Mean Absolute Percentage Error (MAPE)	0.090
u Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.905
Mean Squared Error (MSE)	6.424
Root Mean Squared Error (RMSE)	2.535
Mean Absolute Percentage Error (MAPE)	1.071
v Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.522
Mean Squared Error (MSE)	3.335
Root Mean Squared Error (RMSE)	1.826
Mean Absolute Percentage Error (MAPE)	0.963

CASE2 SCALE PRIOR3	
Air Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	0.676
Mean Squared Error (MSE)	1.285
Root Mean Squared Error (RMSE)	1.134
Mean Absolute Percentage Error (MAPE)	0.035
Water Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	0.213
Mean Squared Error (MSE)	0.077
Root Mean Squared Error (RMSE)	0.278
Mean Absolute Percentage Error (MAPE)	0.011
Sea Level Pressure Test forecast model error (hPa)	
Mean Absolute Error (MAE)	0.531
Mean Squared Error (MSE)	0.419
Root Mean Squared Error (RMSE)	0.648
Mean Absolute Percentage Error (MAPE)	0.001
Relative Humidity Test forecast model error (%)	
Mean Absolute Error (MAE)	6.806
Mean Squared Error (MSE)	83.914
Root Mean Squared Error (RMSE)	9.160
Mean Absolute Percentage Error (MAPE)	0.097
u Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.945
Mean Squared Error (MSE)	6.656
Root Mean Squared Error (RMSE)	2.580
Mean Absolute Percentage Error (MAPE)	1.116
v Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.413
Mean Squared Error (MSE)	3.007
Root Mean Squared Error (RMSE)	1.734
Mean Absolute Percentage Error (MAPE)	0.895

MSE values are squared units.

Table 56. Metrics for Buoy 21 DT Case2 prior 3 6-hr nowcast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

NOWCAST CASE2 NO SCALE PRIOR3		NOWCAST CASE2 SCALE PRIOR3	
Air Temperature 6hr forecast model error (C)		Air Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	2.300	Mean Absolute Error (MAE)	2.417
Mean Squared Error (MSE)	5.850	Mean Squared Error (MSE)	6.095
Root Mean Squared Error (RMSE)	2.419	Root Mean Squared Error (RMSE)	2.469
Mean Absolute Percentage Error (MAPE)	0.150	Mean Absolute Percentage Error (MAPE)	0.156
Water Temperature 6hr forecast model error (C)		Water Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	2.692	Mean Absolute Error (MAE)	4.468
Mean Squared Error (MSE)	7.254	Mean Squared Error (MSE)	20.684
Root Mean Squared Error (RMSE)	2.693	Root Mean Squared Error (RMSE)	4.548
Mean Absolute Percentage Error (MAPE)	0.180	Mean Absolute Percentage Error (MAPE)	0.300
Sea Level Pressure 6hr forecast model error (hPa)		Sea Level Pressure 6hr forecast model error (hPa)	
Mean Absolute Error (MAE)	3.390	Mean Absolute Error (MAE)	3.502
Mean Squared Error (MSE)	11.800	Mean Squared Error (MSE)	18.755
Root Mean Squared Error (RMSE)	3.435	Root Mean Squared Error (RMSE)	4.331
Mean Absolute Percentage Error (MAPE)	0.003	Mean Absolute Percentage Error (MAPE)	0.003
Relative Humidity 6hr forecast model error (%)		Relative Humidity 6hr forecast model error (%)	
Mean Absolute Error (MAE)	5.800	Mean Absolute Error (MAE)	12.717
Mean Squared Error (MSE)	61.483	Mean Squared Error (MSE)	210.185
Root Mean Squared Error (RMSE)	7.841	Root Mean Squared Error (RMSE)	14.498
Mean Absolute Percentage Error (MAPE)	0.075	Mean Absolute Percentage Error (MAPE)	0.170
u 6hr forecast model error (m s^{-1})		u 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.961	Mean Absolute Error (MAE)	2.258
Mean Squared Error (MSE)	4.561	Mean Squared Error (MSE)	6.167
Root Mean Squared Error (RMSE)	2.136	Root Mean Squared Error (RMSE)	2.483
Mean Absolute Percentage Error (MAPE)	10.905	Mean Absolute Percentage Error (MAPE)	6.210
v 6hr forecast model error (m s^{-1})		v 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	2.195	Mean Absolute Error (MAE)	3.234
Mean Squared Error (MSE)	6.507	Mean Squared Error (MSE)	13.994
Root Mean Squared Error (RMSE)	2.551	Root Mean Squared Error (RMSE)	3.741
Mean Absolute Percentage Error (MAPE)	0.574	Mean Absolute Percentage Error (MAPE)	0.802

MSE values are squared units.

Table 57. Buoy 21 DT Case2 Prior 1 6-hr nowcast no scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-21 05:52:48	17.8	17.61	1010.18	75.5	5.234779	-0.370110
2017-10-21 06:52:48	18.3	17.61	1010.18	70.6	5.234779	-5.307543
2017-10-21 07:52:48	18.3	17.61	1010.18	75.5	3.761606	-0.370110
2017-10-21 08:52:48	17.8	17.61	1011.54	65.7	2.532190	-5.286217
2017-10-21 09:52:48	18.3	17.61	1012.22	65.7	2.532190	-5.559715
2017-10-21 10:52:48	16.7	17.70	1012.22	65.7	3.761606	-5.051313

Table 58. Buoy 21 DT Case2 Prior 1 6-hr nowcast scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-21 05:52:48	18.5	20.71	1008.15	89.3	2.650778	1.871800
2017-10-21 06:52:48	18.5	19.58	1008.15	86.7	4.648658	-2.104443
2017-10-21 07:52:48	18.6	19.56	1008.83	88.9	5.372976	1.322990
2017-10-21 08:52:48	18.1	19.51	1010.86	75.5	-0.337446	-1.621146
2017-10-21 09:52:48	17.7	18.81	1014.93	53.7	1.291154	-5.286217
2017-10-21 10:52:48	16.5	18.24	1014.93	60.5	-2.133577	-5.038866

3. BUOY21 Case 3 DT No Scale/Scale Factor, with prior 3 hours comparison

Table 59. Metrics for Buoy 21 DT Case3 prior 3 test data forecast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

CASE3 NO SCALE PRIOR3		CASE3 SCALE PRIOR3	
Air Temperature Test forecast model error (C)		Air Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	2.508	Mean Absolute Error (MAE)	2.473
Mean Squared Error (MSE)	13.566	Mean Squared Error (MSE)	13.469
Root Mean Squared Error (RMSE)	3.683	Root Mean Squared Error (RMSE)	3.670
Mean Absolute Percentage Error (MAPE)	0.098	Mean Absolute Percentage Error (MAPE)	0.096
Water Temperature Test forecast model error (C)		Water Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	1.216	Mean Absolute Error (MAE)	1.221
Mean Squared Error (MSE)	2.336	Mean Squared Error (MSE)	2.281
Root Mean Squared Error (RMSE)	1.528	Root Mean Squared Error (RMSE)	1.510
Mean Absolute Percentage Error (MAPE)	0.077	Mean Absolute Percentage Error (MAPE)	0.077
Sea Level Pressure Test forecast model error (hPa)		Sea Level Pressure Test forecast model error (hPa)	
Mean Absolute Error (MAE)	0.640	Mean Absolute Error (MAE)	0.649
Mean Squared Error (MSE)	0.687	Mean Squared Error (MSE)	0.735
Root Mean Squared Error (RMSE)	0.829	Root Mean Squared Error (RMSE)	0.857
Mean Absolute Percentage Error (MAPE)	0.001	Mean Absolute Percentage Error (MAPE)	0.001
Relative Humidity Test forecast model error (%)		Relative Humidity Test forecast model error (%)	
Mean Absolute Error (MAE)	14.678	Mean Absolute Error (MAE)	13.544
Mean Squared Error (MSE)	325.197	Mean Squared Error (MSE)	283.533
Root Mean Squared Error (RMSE)	18.033	Root Mean Squared Error (RMSE)	16.838
Mean Absolute Percentage Error (MAPE)	0.391	Mean Absolute Percentage Error (MAPE)	0.352
u Test forecast model error ($m\ s^{-1}$)		u Test forecast model error ($m\ s^{-1}$)	
Mean Absolute Error (MAE)	3.237	Mean Absolute Error (MAE)	3.265
Mean Squared Error (MSE)	15.969	Mean Squared Error (MSE)	16.860
Root Mean Squared Error (RMSE)	3.996	Root Mean Squared Error (RMSE)	4.106
Mean Absolute Percentage Error (MAPE)	1.937	Mean Absolute Percentage Error (MAPE)	1.820
v Test forecast model error ($m\ s^{-1}$)		v Test forecast model error ($m\ s^{-1}$)	
Mean Absolute Error (MAE)	2.645	Mean Absolute Error (MAE)	2.738
Mean Squared Error (MSE)	15.722	Mean Squared Error (MSE)	16.697
Root Mean Squared Error (RMSE)	3.965	Root Mean Squared Error (RMSE)	4.086
Mean Absolute Percentage Error (MAPE)	1.338	Mean Absolute Percentage Error (MAPE)	1.363

MSE values are squared units.

Table 60. Metrics for Buoy 21 DT Case3 prior 3 6-hr nowcast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

NOWCAST CASE3 NO SCALE PRIOR3		NOWCAST CASE3 SCALE PRIOR3	
Air Temperature 6hr forecast model error (C)		Air Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	0.850	Mean Absolute Error (MAE)	2.083
Mean Squared Error (MSE)	1.225	Mean Squared Error (MSE)	7.405
Root Mean Squared Error (RMSE)	1.107	Root Mean Squared Error (RMSE)	2.721
Mean Absolute Percentage Error (MAPE)	0.042	Mean Absolute Percentage Error (MAPE)	0.100
Water Temperature 6hr forecast model error (C)		Water Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	0.947	Mean Absolute Error (MAE)	0.940
Mean Squared Error (MSE)	1.060	Mean Squared Error (MSE)	1.623
Root Mean Squared Error (RMSE)	1.030	Root Mean Squared Error (RMSE)	1.274
Mean Absolute Percentage Error (MAPE)	0.048	Mean Absolute Percentage Error (MAPE)	0.048
Sea Level Pressure 6hr forecast model error (hPa)		Sea Level Pressure 6hr forecast model error (hPa)	
Mean Absolute Error (MAE)	0.397	Mean Absolute Error (MAE)	2.430
Mean Squared Error (MSE)	0.400	Mean Squared Error (MSE)	12.323
Root Mean Squared Error (RMSE)	0.633	Root Mean Squared Error (RMSE)	3.510
Mean Absolute Percentage Error (MAPE)	0.000	Mean Absolute Percentage Error (MAPE)	0.002
Relative Humidity 6hr forecast model error (%)		Relative Humidity 6hr forecast model error (%)	
Mean Absolute Error (MAE)	11.700	Mean Absolute Error (MAE)	14.600
Mean Squared Error (MSE)	155.030	Mean Squared Error (MSE)	234.513
Root Mean Squared Error (RMSE)	12.451	Root Mean Squared Error (RMSE)	15.314
Mean Absolute Percentage Error (MAPE)	0.199	Mean Absolute Percentage Error (MAPE)	0.249
u 6hr forecast model error (m s^{-1})		u 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	2.747	Mean Absolute Error (MAE)	3.428
Mean Squared Error (MSE)	14.183	Mean Squared Error (MSE)	15.503
Root Mean Squared Error (RMSE)	3.766	Root Mean Squared Error (RMSE)	3.937
Mean Absolute Percentage Error (MAPE)	2.202	Mean Absolute Percentage Error (MAPE)	3.100
v 6hr forecast model error (m s^{-1})		v 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	3.903	Mean Absolute Error (MAE)	3.138
Mean Squared Error (MSE)	15.707	Mean Squared Error (MSE)	16.314
Root Mean Squared Error (RMSE)	3.963	Root Mean Squared Error (RMSE)	4.039
Mean Absolute Percentage Error (MAPE)	1.324	Mean Absolute Percentage Error (MAPE)	1.114

MSE values are squared units.

Table 61. Buoy 21 DT Case3 Prior 1 6-hr nowcast no scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-26 03:52:45	22.1	21.13	1009.51	73.6	0.257642	2.594964
2017-10-26 04:52:45	21.6	20.76	1008.15	73.6	2.819007	0.579567
2017-10-26 05:52:45	20.7	21.13	1008.83	73.6	3.168709	0.914249
2017-10-26 06:52:45	22.1	19.87	1008.83	62.4	2.819007	0.579567
2017-10-26 07:52:45	21.4	20.66	1008.83	63.1	3.290734	-0.061243
2017-10-26 08:52:45	22.1	20.40	1008.83	63.1	3.290734	-0.061243

Table 62. Buoy 21 DT Case3 Prior 1 6-hr nowcast scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-26 03:52:45	19.6	20.25	1017.30	73.0	-3.049796	0.825271
2017-10-26 04:52:45	21.6	19.88	1011.54	71.4	5.106903	-4.726898
2017-10-26 05:52:45	21.3	20.92	1009.51	72.7	3.145242	-1.928393
2017-10-26 06:52:45	18.9	17.61	1011.54	64.7	0.372294	-4.726898
2017-10-26 07:52:45	16.4	17.55	1010.52	75.9	0.549130	-1.382530
2017-10-26 08:52:45	16.2	18.94	1009.51	88.1	1.783179	-5.741816

4. BUOY22 Case 1 DT No Scale/Scale Factor, with prior 3 hours comparison

Table 63. Metrics for Buoy 22 DT Case1 prior 3 test data forecast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

CASE1 No Scale Prior 3		CASE1 SCALE Prior 3	
Air Temperature Test forecast model error (C)		Air Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	0.431	Mean Absolute Error (MAE)	0.488
Mean Squared Error (MSE)	0.332	Mean Squared Error (MSE)	0.389
Root Mean Squared Error (RMSE)	0.576	Root Mean Squared Error (RMSE)	0.624
Mean Absolute Percentage Error (MAPE)	0.024	Mean Absolute Percentage Error (MAPE)	0.027
Water Temperature Test forecast model error (C)		Water Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	0.138	Mean Absolute Error (MAE)	0.137
Mean Squared Error (MSE)	0.040	Mean Squared Error (MSE)	0.043
Root Mean Squared Error (RMSE)	0.200	Root Mean Squared Error (RMSE)	0.206
Mean Absolute Percentage Error (MAPE)	0.007	Mean Absolute Percentage Error (MAPE)	0.007
Sea Level Pressure Test forecast model error (hPa)		Sea Level Pressure Test forecast model error (hPa)	
Mean Absolute Error (MAE)	0.488	Mean Absolute Error (MAE)	0.578
Mean Squared Error (MSE)	0.381	Mean Squared Error (MSE)	0.497
Root Mean Squared Error (RMSE)	0.618	Root Mean Squared Error (RMSE)	0.705
Mean Absolute Percentage Error (MAPE)	0.000	Mean Absolute Percentage Error (MAPE)	0.001
Relative Humidity Test forecast model error (%)		Relative Humidity Test forecast model error (%)	
Mean Absolute Error (MAE)	3.117	Mean Absolute Error (MAE)	3.589
Mean Squared Error (MSE)	21.245	Mean Squared Error (MSE)	26.104
Root Mean Squared Error (RMSE)	4.609	Root Mean Squared Error (RMSE)	5.109
Mean Absolute Percentage Error (MAPE)	0.040	Mean Absolute Percentage Error (MAPE)	0.046
u Test forecast model error (m s^{-1})		u Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.254	Mean Absolute Error (MAE)	1.555
Mean Squared Error (MSE)	2.892	Mean Squared Error (MSE)	4.410
Root Mean Squared Error (RMSE)	1.701	Root Mean Squared Error (RMSE)	2.100
Mean Absolute Percentage Error (MAPE)	1.192	Mean Absolute Percentage Error (MAPE)	1.240
v Test forecast model error (m s^{-1})		v Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.098	Mean Absolute Error (MAE)	0.952
Mean Squared Error (MSE)	2.078	Mean Squared Error (MSE)	1.609
Root Mean Squared Error (RMSE)	1.442	Root Mean Squared Error (RMSE)	1.268
Mean Absolute Percentage Error (MAPE)	1.881	Mean Absolute Percentage Error (MAPE)	1.363

MSE values are squared units.

Table 64. Metrics for Buoy 22 DT Case1 prior 3 6-hr nowcast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

Nowcast CASE1 No Scale Prior3			Nowcast CASE1 SCALE Prior3	
Air Temperature 6hr forecast model error (C)			Air Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	0.243		Mean Absolute Error (MAE)	0.951
Mean Squared Error (MSE)	0.076		Mean Squared Error (MSE)	2.393
Root Mean Squared Error (RMSE)	0.276		Root Mean Squared Error (RMSE)	1.547
Root Mean Squared Error (RMSE)	0.013		Mean Absolute Percentage Error (MAPE)	0.052
Water Temperature 6hr forecast model error (C)			Water Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	0.120		Mean Absolute Error (MAE)	0.737
Mean Squared Error (MSE)	0.017		Mean Squared Error (MSE)	0.799
Root Mean Squared Error (RMSE)	0.129		Root Mean Squared Error (RMSE)	0.894
Mean Absolute Percentage Error (MAPE)	0.006		Mean Absolute Percentage Error (MAPE)	0.038
Sea Level Pressure 6hr forecast model error (hPa)			Sea Level Pressure 6hr forecast model error (hPa)	
Mean Absolute Error (MAE)	1.243		Mean Absolute Error (MAE)	2.694
Mean Squared Error (MSE)	1.854		Mean Squared Error (MSE)	10.572
Root Mean Squared Error (RMSE)	1.362		Root Mean Squared Error (RMSE)	3.251
Mean Absolute Percentage Error (MAPE)	0.001		Mean Absolute Percentage Error (MAPE)	0.003
Relative Humidity 6hr forecast model error (%)			Relative Humidity 6hr forecast model error(%)	
Mean Absolute Error (MAE)	9.623		Mean Absolute Error (MAE)	5.588
Mean Squared Error (MSE)	159.026		Mean Squared Error (MSE)	52.495
Root Mean Squared Error (RMSE)	12.611		Root Mean Squared Error (RMSE)	7.245
Mean Absolute Percentage Error (MAPE)	0.122		Mean Absolute Percentage Error (MAPE)	0.074
u 6hr forecast model error (m s^{-1})			u 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	2.536		Mean Absolute Error (MAE)	3.552
Mean Squared Error (MSE)	7.989		Mean Squared Error (MSE)	30.455
Root Mean Squared Error (RMSE)	2.827		Root Mean Squared Error (RMSE)	5.519
Mean Absolute Percentage Error (MAPE)	1.507		Mean Absolute Percentage Error (MAPE)	0.888
v 6hr forecast model error (m s^{-1})			v 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.266		Mean Absolute Error (MAE)	1.780
Mean Squared Error (MSE)	2.238		Mean Squared Error (MSE)	4.956
Root Mean Squared Error (RMSE)	1.496		Root Mean Squared Error (RMSE)	2.226
Mean Absolute Percentage Error (MAPE)	2.598		Mean Absolute Percentage Error (MAPE)	2.733

MSE values are squared units.

Table 65. Buoy 22 DT Case1 Prior 1 6-hr nowcast no scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-13 00:00:00	18.325	19.25	1013.4850	55.280000	2.766774	1.684203
2017-10-13 01:00:00	18.100	19.28	1014.2500	66.525000	2.766774	1.684203
2017-10-13 02:00:00	18.100	19.28	1014.2500	79.500000	3.499232	-0.712564
2017-10-13 03:00:00	18.100	19.28	1013.3150	79.500000	5.061609	-0.714088
2017-10-13 04:00:00	18.025	19.28	1012.3025	79.500000	5.061609	-1.173048
2017-10-13 05:00:00	18.025	19.28	1012.3025	69.666667	5.191730	-1.173048

Table 66. Buoy 22 DT Case1 Prior 1 6-hr nowcast scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-13 00:00:00	21.900	19.0650	1014.023333	80.066667	-6.858288	-0.310273
2017-10-13 01:00:00	18.975	19.6000	1012.725000	81.600000	-0.272826	-1.396050
2017-10-13 02:00:00	18.050	19.7100	1011.370000	74.525000	4.678827	2.720038
2017-10-13 03:00:00	17.875	20.1460	1009.850000	83.225000	3.873433	-4.209267
2017-10-13 04:00:00	18.350	20.9775	1008.320000	86.625000	2.362163	-2.348547
2017-10-13 05:00:00	18.525	20.4975	1007.810000	86.775000	0.449084	1.157344

5. BUOY22 Case 2 DT No Scale/Scale Factor, with prior 3 hours comparison

Table 67. Metrics for Buoy 22 DT Case2 prior 3 test data forecast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

CASE2 No Scale Prior 3		CASE2 SCALE Prior 3	
Air Temperature Test forecast model error (C)		Air Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	0.376	Mean Absolute Error (MAE)	0.343
Mean Squared Error (MSE)	0.203	Mean Squared Error (MSE)	0.176
Root Mean Squared Error (RMSE)	0.451	Root Mean Squared Error (RMSE)	0.420
Mean Absolute Percentage Error (MAPE)	0.019	Mean Absolute Percentage Error (MAPE)	0.017
Water Temperature Test forecast model error (C)		Water Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	0.134	Mean Absolute Error (MAE)	0.127
Mean Squared Error (MSE)	0.028	Mean Squared Error (MSE)	0.025
Root Mean Squared Error (RMSE)	0.166	Root Mean Squared Error (RMSE)	0.157
Mean Absolute Percentage Error (MAPE)	0.007	Mean Absolute Percentage Error (MAPE)	0.006
Sea Level Pressure Test forecast model error (hPa)		Sea Level Pressure Test forecast model error (hPa)	
Mean Absolute Error (MAE)	0.428	Mean Absolute Error (MAE)	0.376
Mean Squared Error (MSE)	0.275	Mean Squared Error (MSE)	0.211
Root Mean Squared Error (RMSE)	0.525	Root Mean Squared Error (RMSE)	0.459
Mean Absolute Percentage Error (MAPE)	0.000	Mean Absolute Percentage Error (MAPE)	0.000
Relative Humidity Test forecast model error (%)		Relative Humidity Test forecast model error (%)	
Mean Absolute Error (MAE)	4.506	Mean Absolute Error (MAE)	4.654
Mean Squared Error (MSE)	32.605	Mean Squared Error (MSE)	33.246
Root Mean Squared Error (RMSE)	5.710	Root Mean Squared Error (RMSE)	5.766
Mean Absolute Percentage Error (MAPE)	0.063	Mean Absolute Percentage Error (MAPE)	0.064
u Test forecast model error (m s^{-1})		u Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.862	Mean Absolute Error (MAE)	1.916
Mean Squared Error (MSE)	6.258	Mean Squared Error (MSE)	6.748
Root Mean Squared Error (RMSE)	2.502	Root Mean Squared Error (RMSE)	2.598
Mean Absolute Percentage Error (MAPE)	0.798	Mean Absolute Percentage Error (MAPE)	0.743
v Test forecast model error (m s^{-1})		v Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.329	Mean Absolute Error (MAE)	1.342
Mean Squared Error (MSE)	3.334	Mean Squared Error (MSE)	3.322
Root Mean Squared Error (RMSE)	1.826	Root Mean Squared Error (RMSE)	1.823
Mean Absolute Percentage Error (MAPE)	1.440	Mean Absolute Percentage Error (MAPE)	1.266

MSE values are squared units.

Table 68. Metrics for Buoy 22 DT Case2 prior 3 6-hr nowcast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

Nowcast CASE2 No Scale Prior3		Nowcast CASE2 SCALE Prior3	
Air Temperature 6hr forecast model error (C)		Air Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	0.983	Mean Absolute Error (MAE)	2.094
Mean Squared Error (MSE)	1.016	Mean Squared Error (MSE)	4.896
Root Mean Squared Error (RMSE)	1.008	Root Mean Squared Error (RMSE)	2.213
Mean Absolute Percentage Error (MAPE)	0.058	Mean Absolute Percentage Error (MAPE)	0.122
Water Temperature 6hr forecast model error (C)		Water Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	0.896	Mean Absolute Error (MAE)	1.740
Mean Squared Error (MSE)	0.964	Mean Squared Error (MSE)	3.451
Root Mean Squared Error (RMSE)	0.982	Root Mean Squared Error (RMSE)	1.858
Mean Absolute Percentage Error (MAPE)	0.049	Mean Absolute Percentage Error (MAPE)	0.095
Sea Level Pressure 6hr forecast model error (hPa)		Sea Level Pressure 6hr forecast model error (hPa)	
Mean Absolute Error (MAE)	2.485	Mean Absolute Error (MAE)	3.148
Mean Squared Error (MSE)	6.399	Mean Squared Error (MSE)	13.186
Root Mean Squared Error (RMSE)	2.530	Root Mean Squared Error (RMSE)	3.631
Mean Absolute Percentage Error (MAPE)	0.002	Mean Absolute Percentage Error (MAPE)	0.003
Relative Humidity 6hr forecast model error (%)		Relative Humidity 6hr forecast model error (%)	
Mean Absolute Error (MAE)	3.292	Mean Absolute Error (MAE)	13.140
Mean Squared Error (MSE)	11.388	Mean Squared Error (MSE)	177.641
Root Mean Squared Error (RMSE)	3.375	Root Mean Squared Error (RMSE)	13.328
Mean Absolute Percentage Error (MAPE)	0.048	Mean Absolute Percentage Error (MAPE)	0.191
u 6hr forecast model error (m s^{-1})		u 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	4.199	Mean Absolute Error (MAE)	4.022
Mean Squared Error (MSE)	22.753	Mean Squared Error (MSE)	20.213
Root Mean Squared Error (RMSE)	4.770	Root Mean Squared Error (RMSE)	4.496
Mean Absolute Percentage Error (MAPE)	0.708	Mean Absolute Percentage Error (MAPE)	1.851
v 6hr forecast model error (m s^{-1})		v 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.511	Mean Absolute Error (MAE)	3.909
Mean Squared Error (MSE)	2.787	Mean Squared Error (MSE)	21.598
Root Mean Squared Error (RMSE)	1.670	Root Mean Squared Error (RMSE)	4.647
Mean Absolute Percentage Error (MAPE)	0.364	Mean Absolute Percentage Error (MAPE)	0.724

MSE values are squared units.

Table 69. Buoy 22 DT Case2 Prior 1 6-hr nowcast no scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-21 06:00:00	18.650	20.070000	1011.200	67.250	1.022332	-4.830859
2017-10-21 07:00:00	18.450	19.575000	1011.200	67.250	1.022332	-6.557079
2017-10-21 08:00:00	18.150	19.301250	1011.200	65.225	1.022332	-6.557079
2017-10-21 09:00:00	18.100	18.653333	1012.560	65.225	1.022332	-6.557079
2017-10-21 10:00:00	17.625	18.653333	1012.560	65.225	1.022332	-6.360915
2017-10-21 11:00:00	17.500	18.653333	1013.145	61.500	1.022332	-4.521350

Table 70. Buoy 22 DT Case2 Prior 1 6-hr nowcast scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-21 06:00:00	20.600000	21.487500	1009.5075	81.950000	3.404533	1.007675
2017-10-21 07:00:00	19.900000	20.432500	1008.9150	84.466667	5.034425	-0.374981
2017-10-21 08:00:00	19.625000	20.032500	1009.1700	79.250000	5.383925	-1.939070
2017-10-21 09:00:00	18.500000	19.600000	1012.8900	81.775000	-0.104402	0.421661
2017-10-21 10:00:00	18.150000	19.280000	1013.8250	87.550000	-0.885950	-4.209267
2017-10-21 11:00:00	18.366667	19.133333	1016.6200	75.275000	-5.937953	-3.878100

6. BUOY22 Case 3 DT No Scale/Scale Factor, with prior 3 hours comparison

Table 71. Metrics for Buoy 22 DT Case3 prior 3 test data forecast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

CASE3 No Scale Prior 3		CASE3 SCALE Prior 3	
Air Temperature Test forecast model error (C)		Air Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	1.494	Mean Absolute Error (MAE)	1.626
Mean Squared Error (MSE)	6.072	Mean Squared Error (MSE)	7.153
Root Mean Squared Error (RMSE)	2.464	Root Mean Squared Error (RMSE)	2.675
Mean Absolute Percentage Error (MAPE)	0.061	Mean Absolute Percentage Error (MAPE)	0.067
Water Temperature Test forecast model error (C)		Water Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	0.244	Mean Absolute Error (MAE)	0.252
Mean Squared Error (MSE)	0.096	Mean Squared Error (MSE)	0.098
Root Mean Squared Error (RMSE)	0.310	Root Mean Squared Error (RMSE)	0.313
Mean Absolute Percentage Error (MAPE)	0.013	Mean Absolute Percentage Error (MAPE)	0.013
Sea Level Pressure Test forecast model error (hPa)		Sea Level Pressure Test forecast model error (hPa)	
Mean Absolute Error (MAE)	0.524	Mean Absolute Error (MAE)	0.568
Mean Squared Error (MSE)	0.501	Mean Squared Error (MSE)	0.555
Root Mean Squared Error (RMSE)	0.708	Root Mean Squared Error (RMSE)	0.745
Mean Absolute Percentage Error (MAPE)	0.001	Mean Absolute Percentage Error (MAPE)	0.001
Relative Humidity Test forecast model error (%)		Relative Humidity Test forecast model error (%)	
Mean Absolute Error (MAE)	11.189	Mean Absolute Error (MAE)	10.238
Mean Squared Error (MSE)	213.852	Mean Squared Error (MSE)	187.215
Root Mean Squared Error (RMSE)	14.624	Root Mean Squared Error (RMSE)	13.683
Mean Absolute Percentage Error (MAPE)	0.243	Mean Absolute Percentage Error (MAPE)	0.222
u Test forecast model error ($m\ s^{-1}$)		u Test forecast model error ($m\ s^{-1}$)	
Mean Absolute Error (MAE)	2.321	Mean Absolute Error (MAE)	2.208
Mean Squared Error (MSE)	9.531	Mean Squared Error (MSE)	9.419
Root Mean Squared Error (RMSE)	3.087	Root Mean Squared Error (RMSE)	3.069
Mean Absolute Percentage Error (MAPE)	3.369	Mean Absolute Percentage Error (MAPE)	3.165
v Test forecast model error ($m\ s^{-1}$)		v Test forecast model error ($m\ s^{-1}$)	
Mean Absolute Error (MAE)	1.684	Mean Absolute Error (MAE)	1.594
Mean Squared Error (MSE)	4.669	Mean Squared Error (MSE)	4.349
Root Mean Squared Error (RMSE)	2.161	Root Mean Squared Error (RMSE)	2.085
Mean Absolute Percentage Error (MAPE)	1.356	Mean Absolute Percentage Error (MAPE)	1.288

MSE values are squared units.

Table 72. Metrics for Buoy 22 DT Case3 prior 3 6-hr nowcast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

Nowcast CASE3 No Scale Prior3		Nowcast CASE3 SCALE Prior3	
Air Temperature 6hr forecast model error (C)		Air Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	0.422	Mean Absolute Error (MAE)	2.565
Mean Squared Error (MSE)	0.282	Mean Squared Error (MSE)	8.806
Root Mean Squared Error (RMSE)	0.531	Root Mean Squared Error (RMSE)	2.968
Mean Absolute Percentage Error (MAPE)	0.020	Mean Absolute Percentage Error (MAPE)	0.120
Water Temperature 6hr forecast model error (C)		Water Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	1.515	Mean Absolute Error (MAE)	0.699
Mean Squared Error (MSE)	2.420	Mean Squared Error (MSE)	0.597
Root Mean Squared Error (RMSE)	1.556	Root Mean Squared Error (RMSE)	0.773
Mean Absolute Percentage Error (MAPE)	0.076	Mean Absolute Percentage Error (MAPE)	0.035
Sea Level Pressure 6hr forecast model error (hPa)		Sea Level Pressure 6hr forecast model error (hPa)	
Mean Absolute Error (MAE)	0.550	Mean Absolute Error (MAE)	2.985
Mean Squared Error (MSE)	0.357	Mean Squared Error (MSE)	14.706
Root Mean Squared Error (RMSE)	0.597	Root Mean Squared Error (RMSE)	3.835
Mean Absolute Percentage Error (MAPE)	0.001	Mean Absolute Percentage Error (MAPE)	0.003
Relative Humidity 6hr forecast model error (%)		Relative Humidity 6hr forecast model error (%)	
Mean Absolute Error (MAE)	6.244	Mean Absolute Error (MAE)	14.312
Mean Squared Error (MSE)	54.979	Mean Squared Error (MSE)	269.581
Root Mean Squared Error (RMSE)	7.415	Root Mean Squared Error (RMSE)	16.419
Mean Absolute Percentage Error (MAPE)	0.105	Mean Absolute Percentage Error (MAPE)	0.233
u 6hr forecast model error (m s^{-1})		u 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.620	Mean Absolute Error (MAE)	3.302
Mean Squared Error (MSE)	3.656	Mean Squared Error (MSE)	15.013
Root Mean Squared Error (RMSE)	1.912	Root Mean Squared Error (RMSE)	3.875
Mean Absolute Percentage Error (MAPE)	1.417	Mean Absolute Percentage Error (MAPE)	2.937
v 6hr forecast model error (m s^{-1})		v 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.960	Mean Absolute Error (MAE)	2.228
Mean Squared Error (MSE)	5.853	Mean Squared Error (MSE)	8.734
Root Mean Squared Error (RMSE)	2.419	Root Mean Squared Error (RMSE)	2.955
Mean Absolute Percentage Error (MAPE)	1.059	Mean Absolute Percentage Error (MAPE)	1.560

MSE values are squared units.

Table 73. Buoy 22 DT Case3 Prior 1 6-hr nowcast no scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-26 03:00:00	21.900	21.6425	1010.2675	64.650000	1.683670	0.641960
2017-10-26 04:00:00	21.625	21.6325	1008.7450	57.333333	3.327784	0.902056
2017-10-26 05:00:00	21.350	21.6325	1008.9150	67.975000	3.327784	-0.967056
2017-10-26 06:00:00	21.350	21.7575	1008.9150	67.975000	-0.234589	-0.967056
2017-10-26 07:00:00	21.350	21.0150	1008.9150	70.050000	0.396539	-0.967056
2017-10-26 08:00:00	21.350	20.7150	1009.1700	70.050000	2.660717	-0.967056

Table 74. Buoy 22 DT Case3 Prior 1 6-hr nowcast scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-26 03:00:00	21.900	20.5200	1017.300000	71.575	-3.722994	2.166665
2017-10-26 04:00:00	20.725	20.8375	1013.400000	54.850	3.404533	-0.577826
2017-10-26 05:00:00	19.900	20.4975	1011.200000	82.450	5.120119	-1.507747
2017-10-26 06:00:00	17.275	20.1100	1012.333333	65.325	-0.104402	-2.518703
2017-10-26 07:00:00	17.200	19.2125	1010.097500	84.700	2.579940	-3.050428
2017-10-26 08:00:00	17.650	18.5275	1010.293333	86.375	6.060820	-3.114906

D. RANDOM FOREST

1. BUOY21 Case 1 RF No Scale/Scale Factor, with prior 3 hours comparison

Table 75. Metrics for Buoy 21 RF Case1 prior 3 test data forecast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

CASE1 NO SCALE PRIOR3		CASE1 SCALE PRIOR3	
Air Temperature Test forecast model error (C)		Air Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	0.560	Mean Absolute Error (MAE)	0.571
Mean Squared Error (MSE)	1.157	Mean Squared Error (MSE)	1.146
Root Mean Squared Error (RMSE)	1.076	Root Mean Squared Error (RMSE)	1.071
Mean Absolute Percentage Error (MAPE)	0.029	Mean Absolute Percentage Error (MAPE)	0.029
Water Temperature Test forecast model error (C)		Water Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	0.163	Mean Absolute Error (MAE)	0.142
Mean Squared Error (MSE)	0.048	Mean Squared Error (MSE)	0.039
Root Mean Squared Error (RMSE)	0.219	Root Mean Squared Error (RMSE)	0.197
Mean Absolute Percentage Error (MAPE)	0.008	Mean Absolute Percentage Error (MAPE)	0.007
Sea Level Pressure Test forecast model error (hPa)		Sea Level Pressure Test forecast model error (hPa)	
Mean Absolute Error (MAE)	0.389	Mean Absolute Error (MAE)	0.381
Mean Squared Error (MSE)	0.228	Mean Squared Error (MSE)	0.217
Root Mean Squared Error (RMSE)	0.478	Root Mean Squared Error (RMSE)	0.466
Mean Absolute Percentage Error (MAPE)	0.000	Mean Absolute Percentage Error (MAPE)	0.000
Relative Humidity Test forecast model error (%)		Relative Humidity Test forecast model error (%)	
Mean Absolute Error (MAE)	3.766	Mean Absolute Error (MAE)	3.668
Mean Squared Error (MSE)	76.605	Mean Squared Error (MSE)	77.002
Root Mean Squared Error (RMSE)	8.752	Root Mean Squared Error (RMSE)	8.775
Mean Absolute Percentage Error (MAPE)	0.086	Mean Absolute Percentage Error (MAPE)	0.085
u Test forecast model error ($m\ s^{-1}$)		u Test forecast model error ($m\ s^{-1}$)	
Mean Absolute Error (MAE)	1.262	Mean Absolute Error (MAE)	1.288
Mean Squared Error (MSE)	3.810	Mean Squared Error (MSE)	3.870
Root Mean Squared Error (RMSE)	1.952	Root Mean Squared Error (RMSE)	1.967
Mean Absolute Percentage Error (MAPE)	1.020	Mean Absolute Percentage Error (MAPE)	0.982
v Test forecast model error ($m\ s^{-1}$)		v Test forecast model error ($m\ s^{-1}$)	
Mean Absolute Error (MAE)	1.022	Mean Absolute Error (MAE)	1.008
Mean Squared Error (MSE)	2.315	Mean Squared Error (MSE)	2.298
Root Mean Squared Error (RMSE)	1.522	Root Mean Squared Error (RMSE)	1.516
Mean Absolute Percentage Error (MAPE)	0.593	Mean Absolute Percentage Error (MAPE)	0.588

MSE values are squared units.

Table 76. Metrics for Buoy 21 RF Case1 prior 3 6-hr nowcast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

NOWCAST CASE1 NO SCALE PRIOR3		NOWCAST CASE1 SCALE PRIOR3	
Air Temperature 6hr forecast model error (C)		Air Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	0.788	Mean Absolute Error (MAE)	1.196
Mean Squared Error (MSE)	0.977	Mean Squared Error (MSE)	2.349
Root Mean Squared Error (RMSE)	0.988	Root Mean Squared Error (RMSE)	1.533
Mean Absolute Percentage Error (MAPE)	0.042	Mean Absolute Percentage Error (MAPE)	0.065
Water Temperature 6hr forecast model error (C)		Water Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	0.166	Mean Absolute Error (MAE)	0.774
Mean Squared Error (MSE)	0.035	Mean Squared Error (MSE)	0.944
Root Mean Squared Error (RMSE)	0.187	Root Mean Squared Error (RMSE)	0.972
Mean Absolute Percentage Error (MAPE)	0.008	Mean Absolute Percentage Error (MAPE)	0.039
Sea Level Pressure 6hr forecast model error (hPa)		Sea Level Pressure 6hr forecast model error (hPa)	
Mean Absolute Error (MAE)	1.655	Mean Absolute Error (MAE)	2.384
Mean Squared Error (MSE)	3.772	Mean Squared Error (MSE)	10.687
Root Mean Squared Error (RMSE)	1.942	Root Mean Squared Error (RMSE)	3.269
Mean Absolute Percentage Error (MAPE)	0.002	Mean Absolute Percentage Error (MAPE)	0.002
Relative Humidity 6hr forecast model error (%)		Relative Humidity 6hr forecast model error(%)	
Mean Absolute Error (MAE)	4.386	Mean Absolute Error (MAE)	6.046
Mean Squared Error (MSE)	29.465	Mean Squared Error (MSE)	55.415
Root Mean Squared Error (RMSE)	5.428	Root Mean Squared Error (RMSE)	7.444
Mean Absolute Percentage Error (MAPE)	0.063	Mean Absolute Percentage Error (MAPE)	0.084
u 6hr forecast model error (m s^{-1})		u 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	2.219	Mean Absolute Error (MAE)	2.929
Mean Squared Error (MSE)	5.929	Mean Squared Error (MSE)	13.936
Root Mean Squared Error (RMSE)	2.435	Root Mean Squared Error (RMSE)	3.733
Mean Absolute Percentage Error (MAPE)	0.967	Mean Absolute Percentage Error (MAPE)	0.926
v 6hr forecast model error (m s^{-1})		v 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	0.786	Mean Absolute Error (MAE)	1.725
Mean Squared Error (MSE)	0.958	Mean Squared Error (MSE)	4.337
Root Mean Squared Error (RMSE)	0.979	Root Mean Squared Error (RMSE)	2.082
Mean Absolute Percentage Error (MAPE)	1.550	Mean Absolute Percentage Error (MAPE)	2.744

MSE values are squared units.

Table 77. Buoy 21 RF Case1 prior 3 6-hr nowcast no scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-12 23:52:32	16.677	19.7060	1014.3995	80.419	1.433352	-1.611690
2017-10-13 00:52:32	18.346	19.6238	1014.5960	74.900	1.445566	-1.056721
2017-10-13 01:52:32	18.320	19.6489	1014.4657	77.995	3.393767	-2.172366
2017-10-13 02:52:32	18.546	19.6171	1013.5734	72.857	4.262844	-2.390930
2017-10-13 03:52:32	18.267	19.6814	1012.4117	77.535	4.320726	-0.690732
2017-10-13 04:52:32	18.887	19.6984	1012.2831	74.491	4.337854	-2.539039

Table 78. Buoy 21 RF Case1 prior 3 6-hr nowcast scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-12 23:52:32	16.852	18.09300	1012.4579	86.234	-1.591723	-2.781467
2017-10-13 00:52:32	17.885	18.90290	1012.3704	71.459	-1.759135	-1.614890
2017-10-13 01:52:32	18.446	19.54390	1012.0863	82.258	0.750049	-0.773545
2017-10-13 02:52:32	19.012	19.68000	1010.0164	70.719	3.252826	-0.227159
2017-10-13 03:52:32	19.441	20.08895	1007.2435	79.441	3.231713	1.091457
2017-10-13 04:52:32	20.907	20.78750	1007.3780	71.897	2.665902	-2.525044

2. BUOY 21 Case 2 RF No Scale/Scale Factor, with prior 3 hours comparison

Table 79. Metrics for Buoy 21 RF Case2 prior 3 test data forecast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

CASE2 NO SCALE PRIOR3		CASE2 SCALE PRIOR3	
Air Temperature Test forecast model error (C)		Air Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	0.455	Mean Absolute Error (MAE)	0.448
Mean Squared Error (MSE)	0.674	Mean Squared Error (MSE)	0.624
Root Mean Squared Error (RMSE)	0.821	Root Mean Squared Error (RMSE)	0.790
Mean Absolute Percentage Error (MAPE)	0.023	Mean Absolute Percentage Error (MAPE)	0.023
Water Temperature Test forecast model error (C)		Water Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	0.121	Mean Absolute Error (MAE)	0.124
Mean Squared Error (MSE)	0.037	Mean Squared Error (MSE)	0.039
Root Mean Squared Error (RMSE)	0.193	Root Mean Squared Error (RMSE)	0.198
Mean Absolute Percentage Error (MAPE)	0.006	Mean Absolute Percentage Error (MAPE)	0.007
Sea Level Pressure Test forecast model error (hPa)		Sea Level Pressure Test forecast model error (hPa)	
Mean Absolute Error (MAE)	0.397	Mean Absolute Error (MAE)	0.425
Mean Squared Error (MSE)	0.224	Mean Squared Error (MSE)	0.249
Root Mean Squared Error (RMSE)	0.473	Root Mean Squared Error (RMSE)	0.499
Mean Absolute Percentage Error (MAPE)	0.000	Mean Absolute Percentage Error (MAPE)	0.000
Relative Humidity Test forecast model error (%)		Relative Humidity Test forecast model error (%)	
Mean Absolute Error (MAE)	4.369	Mean Absolute Error (MAE)	4.493
Mean Squared Error (MSE)	41.085	Mean Squared Error (MSE)	42.506
Root Mean Squared Error (RMSE)	6.410	Root Mean Squared Error (RMSE)	6.520
Mean Absolute Percentage Error (MAPE)	0.065	Mean Absolute Percentage Error (MAPE)	0.067
u Test forecast model error (m s^{-1})		u Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.705	Mean Absolute Error (MAE)	1.703
Mean Squared Error (MSE)	5.888	Mean Squared Error (MSE)	6.018
Root Mean Squared Error (RMSE)	2.427	Root Mean Squared Error (RMSE)	2.453
Mean Absolute Percentage Error (MAPE)	0.870	Mean Absolute Percentage Error (MAPE)	0.880
v Test forecast model error (m s^{-1})		v Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	0.875	Mean Absolute Error (MAE)	0.898
Mean Squared Error (MSE)	1.280	Mean Squared Error (MSE)	1.289
Root Mean Squared Error (RMSE)	1.132	Root Mean Squared Error (RMSE)	1.136
Mean Absolute Percentage Error (MAPE)	0.546	Mean Absolute Percentage Error (MAPE)	0.559

MSE values are squared units.

Table 80. Metrics for Buoy 21 RF Case2 prior 3 6-hr nowcast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

NOWCAST CASE2 NO SCALE PRIOR3		NOWCAST CASE2 SCALE PRIOR3	
Air Temperature 6hr forecast model error (C)		Air Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	2.107	Mean Absolute Error (MAE)	3.178
Mean Squared Error (MSE)	4.964	Mean Squared Error (MSE)	10.285
Root Mean Squared Error (RMSE)	2.228	Root Mean Squared Error (RMSE)	3.207
Mean Absolute Percentage Error (MAPE)	0.138	Mean Absolute Percentage Error (MAPE)	0.205
Water Temperature 6hr forecast model error (C)		Water Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	2.682	Mean Absolute Error (MAE)	4.593
Mean Squared Error (MSE)	7.206	Mean Squared Error (MSE)	21.892
Root Mean Squared Error (RMSE)	2.684	Root Mean Squared Error (RMSE)	4.679
Mean Absolute Percentage Error (MAPE)	0.180	Mean Absolute Percentage Error (MAPE)	0.308
Sea Level Pressure 6hr forecast model error (hPa)		Sea Level Pressure 6hr forecast model error (hPa)	
Mean Absolute Error (MAE)	3.200	Mean Absolute Error (MAE)	3.328
Mean Squared Error (MSE)	10.405	Mean Squared Error (MSE)	15.635
Root Mean Squared Error (RMSE)	3.226	Root Mean Squared Error (RMSE)	3.954
Mean Absolute Percentage Error (MAPE)	0.003	Mean Absolute Percentage Error (MAPE)	0.003
Relative Humidity 6hr forecast model error (%)		Relative Humidity 6hr forecast model error (%)	
Mean Absolute Error (MAE)	4.968	Mean Absolute Error (MAE)	9.812
Mean Squared Error (MSE)	56.222	Mean Squared Error (MSE)	116.567
Root Mean Squared Error (RMSE)	7.498	Root Mean Squared Error (RMSE)	10.797
Mean Absolute Percentage Error (MAPE)	0.064	Mean Absolute Percentage Error (MAPE)	0.132
u 6hr forecast model error (m s^{-1})		u 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	2.352	Mean Absolute Error (MAE)	1.837
Mean Squared Error (MSE)	5.985	Mean Squared Error (MSE)	5.435
Root Mean Squared Error (RMSE)	2.446	Root Mean Squared Error (RMSE)	2.331
Mean Absolute Percentage Error (MAPE)	15.621	Mean Absolute Percentage Error (MAPE)	2.225
v 6hr forecast model error (m s^{-1})		v 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.516	Mean Absolute Error (MAE)	3.071
Mean Squared Error (MSE)	2.703	Mean Squared Error (MSE)	12.101
Root Mean Squared Error (RMSE)	1.644	Root Mean Squared Error (RMSE)	3.479
Mean Absolute Percentage Error (MAPE)	0.377	Mean Absolute Percentage Error (MAPE)	0.752

MSE values are squared units.

Table 81. Buoy 21 RF Case2 prior 3 6-hr nowcast no scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-21 05:52:48	17.723	17.6165	1010.5524	74.136	4.077990	-2.023674
2017-10-21 06:52:48	17.856	17.6193	1010.5899	73.333	3.937990	-3.007404
2017-10-21 07:52:48	17.793	17.6169	1010.6001	74.351	3.846081	-2.378788
2017-10-21 08:52:48	17.789	17.6153	1011.4788	66.719	3.647842	-4.005150
2017-10-21 09:52:48	17.795	17.5982	1012.2158	64.926	3.694625	-4.936555
2017-10-21 10:52:48	17.087	17.6266	1012.2229	65.200	4.053409	-4.810019

Table 82. Buoy 21 RF Case2 prior 3 6-hr nowcast scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-21 05:52:48	19.862	20.66475	1008.9447	87.172	3.526577	1.144166
2017-10-21 06:52:48	19.715	20.01180	1008.9960	84.202	4.215453	-1.638794
2017-10-21 07:52:48	18.928	19.80800	1008.9249	85.684	4.491031	0.774902
2017-10-21 08:52:48	18.746	19.58460	1010.9180	77.016	1.572315	-1.134415
2017-10-21 09:52:48	17.938	18.89790	1015.1083	62.869	0.327121	-2.146941
2017-10-21 10:52:48	17.279	18.19250	1015.5009	72.200	-2.906004	-2.439431

3. BUOY21 Case 3 RF No Scale/Scale Factor, with prior 3 hours comparison

Table 83. Metrics for Buoy 21 RF Case3 prior 3 test data forecast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

CASE3 NO SCALE PRIOR3		CASE3 SCALE PRIOR3	
Air Temperature Test forecast model error (C)		Air Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	2.148	Mean Absolute Error (MAE)	2.115
Mean Squared Error (MSE)	10.710	Mean Squared Error (MSE)	10.493
Root Mean Squared Error (RMSE)	3.273	Root Mean Squared Error (RMSE)	3.239
Mean Absolute Percentage Error (MAPE)	0.083	Mean Absolute Percentage Error (MAPE)	0.082
Water Temperature Test forecast model error (C)		Water Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	1.190	Mean Absolute Error (MAE)	1.185
Mean Squared Error (MSE)	2.292	Mean Squared Error (MSE)	2.267
Root Mean Squared Error (RMSE)	1.514	Root Mean Squared Error (RMSE)	1.506
Mean Absolute Percentage Error (MAPE)	0.075	Mean Absolute Percentage Error (MAPE)	0.075
Sea Level Pressure Test forecast model error (hPa)		Sea Level Pressure Test forecast model error (hPa)	
Mean Absolute Error (MAE)	0.557	Mean Absolute Error (MAE)	0.555
Mean Squared Error (MSE)	0.572	Mean Squared Error (MSE)	0.567
Root Mean Squared Error (RMSE)	0.756	Root Mean Squared Error (RMSE)	0.753
Mean Absolute Percentage Error (MAPE)	0.001	Mean Absolute Percentage Error (MAPE)	0.001
Relative Humidity Test forecast model error (%)		Relative Humidity Test forecast model error (%)	
Mean Absolute Error (MAE)	9.879	Mean Absolute Error (MAE)	9.398
Mean Squared Error (MSE)	164.463	Mean Squared Error (MSE)	147.062
Root Mean Squared Error (RMSE)	12.824	Root Mean Squared Error (RMSE)	12.127
Mean Absolute Percentage Error (MAPE)	0.316	Mean Absolute Percentage Error (MAPE)	0.288
u Test forecast model error ($m\ s^{-1}$)		u Test forecast model error ($m\ s^{-1}$)	
Mean Absolute Error (MAE)	2.895	Mean Absolute Error (MAE)	2.930
Mean Squared Error (MSE)	13.125	Mean Squared Error (MSE)	13.273
Root Mean Squared Error (RMSE)	3.623	Root Mean Squared Error (RMSE)	3.643
Mean Absolute Percentage Error (MAPE)	1.493	Mean Absolute Percentage Error (MAPE)	1.408
v Test forecast model error ($m\ s^{-1}$)		v Test forecast model error ($m\ s^{-1}$)	
Mean Absolute Error (MAE)	1.870	Mean Absolute Error (MAE)	1.866
Mean Squared Error (MSE)	6.815	Mean Squared Error (MSE)	6.974
Root Mean Squared Error (RMSE)	2.611	Root Mean Squared Error (RMSE)	2.641
Mean Absolute Percentage Error (MAPE)	0.974	Mean Absolute Percentage Error (MAPE)	0.998

MSE values are squared units.

Table 84. Metrics for Buoy 21 RF Case3 prior 3 6-hr nowcast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

NOWCAST CASE3 NO SCALE PRIOR3		NOWCAST CASE3 SCALE PRIOR3	
Air Temperature 6hr forecast model error (C)		Air Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	0.615	Mean Absolute Error (MAE)	1.942
Mean Squared Error (MSE)	0.625	Mean Squared Error (MSE)	7.129
Root Mean Squared Error (RMSE)	0.791	Root Mean Squared Error (RMSE)	2.67
Mean Absolute Percentage Error (MAPE)	0.030	Mean Absolute Percentage Error (MAPE)	0.093
Water Temperature 6hr forecast model error (C)		Water Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	0.931	Mean Absolute Error (MAE)	0.944
Mean Squared Error (MSE)	1.008	Mean Squared Error (MSE)	1.493
Root Mean Squared Error (RMSE)	1.004	Root Mean Squared Error (RMSE)	1.222
Mean Absolute Percentage Error (MAPE)	0.047	Mean Absolute Percentage Error (MAPE)	0.048
Sea Level Pressure 6hr forecast model error (hPa)		Sea Level Pressure 6hr forecast model error (hPa)	
Mean Absolute Error (MAE)	0.314	Mean Absolute Error (MAE)	2.652
Mean Squared Error (MSE)	0.134	Mean Squared Error (MSE)	12.804
Root Mean Squared Error (RMSE)	0.366	Root Mean Squared Error (RMSE)	3.578
Mean Absolute Percentage Error (MAPE)	0.000	Mean Absolute Percentage Error (MAPE)	0.003
Relative Humidity 6hr forecast model error (%)		Relative Humidity 6hr forecast model error (%)	
Mean Absolute Error (MAE)	7.079	Mean Absolute Error (MAE)	13.768
Mean Squared Error (MSE)	54.268	Mean Squared Error (MSE)	214.303
Root Mean Squared Error (RMSE)	7.367	Root Mean Squared Error (RMSE)	14.639
Mean Absolute Percentage Error (MAPE)	0.120	Mean Absolute Percentage Error (MAPE)	0.234
u 6hr forecast model error (m s^{-1})		u 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.755	Mean Absolute Error (MAE)	3.352
Mean Squared Error (MSE)	7.965	Mean Squared Error (MSE)	14.019
Root Mean Squared Error (RMSE)	2.822	Root Mean Squared Error (RMSE)	3.744
Mean Absolute Percentage Error (MAPE)	1.163	Mean Absolute Percentage Error (MAPE)	2.769
v 6hr forecast model error (m s^{-1})		v 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	2.681	Mean Absolute Error (MAE)	3.726
Mean Squared Error (MSE)	8.783	Mean Squared Error (MSE)	16.952
Root Mean Squared Error (RMSE)	2.964	Root Mean Squared Error (RMSE)	4.117
Mean Absolute Percentage Error (MAPE)	0.914	Mean Absolute Percentage Error (MAPE)	1.281

MSE values are squared units.

Table 85. Buoy 21 RF Case3 Prior 1 6-hr nowcast no scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-26 03:52:45	21.559	21.07770	1010.0462	65.651	0.056138	0.872930
2017-10-26 04:52:45	21.406	21.09860	1009.0643	64.682	0.846647	-1.462359
2017-10-26 05:52:45	21.266	20.93110	1009.0272	63.322	2.000469	-1.335283
2017-10-26 06:52:45	21.180	19.92870	1009.1526	62.557	2.028401	-1.483615
2017-10-26 07:52:45	21.245	20.27520	1009.0407	62.454	1.622713	-1.548283
2017-10-26 08:52:45	21.462	20.54355	1009.0238	63.194	1.545660	-2.294337

Table 86. Buoy 21 RF Case3 Prior 1 6-hr nowcast scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-26 03:52:45	21.472	20.0022	1017.0732	74.381	-3.804018	1.925854
2017-10-26 04:52:45	20.860	19.7188	1012.1192	63.807	4.846620	-0.262625
2017-10-26 05:52:45	20.757	20.9703	1009.8038	77.620	1.700700	-1.736563
2017-10-26 06:52:45	18.800	17.6667	1012.3190	66.387	4.223729	-0.107189
2017-10-26 07:52:45	16.879	17.7390	1010.0327	71.428	0.890287	-0.499795
2017-10-26 08:52:45	15.681	18.9718	1009.9069	87.187	0.637983	-4.286231

4. BUOY22 Case 1 RF No Scale/Scale Factor, with prior 3 hours comparison

Table 87. Metrics for Buoy 22 RF Case1 prior 3 test data forecast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

CASE1 NO SCALE PRIOR3		CASE1 SCALE PRIOR3	
Air Temperature Test forecast model error (C)		Air Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	0.370	Mean Absolute Error (MAE)	0.355
Mean Squared Error (MSE)	0.272	Mean Squared Error (MSE)	0.244
Root Mean Squared Error (RMSE)	0.522	Root Mean Squared Error (RMSE)	0.494
Mean Absolute Percentage Error (MAPE)	0.020	Mean Absolute Percentage Error (MAPE)	0.020
Water Temperature Test forecast model error (C)		Water Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	0.098	Mean Absolute Error (MAE)	0.097
Mean Squared Error (MSE)	0.020	Mean Squared Error (MSE)	0.019
Root Mean Squared Error (RMSE)	0.141	Root Mean Squared Error (RMSE)	0.138
Mean Absolute Percentage Error (MAPE)	0.005	Mean Absolute Percentage Error (MAPE)	0.005
Sea Level Pressure Test forecast model error (hPa)		Sea Level Pressure Test forecast model error (hPa)	
Mean Absolute Error (MAE)	0.293	Mean Absolute Error (MAE)	0.297
Mean Squared Error (MSE)	0.132	Mean Squared Error (MSE)	0.142
Root Mean Squared Error (RMSE)	0.364	Root Mean Squared Error (RMSE)	0.377
Mean Absolute Percentage Error (MAPE)	0.000	Mean Absolute Percentage Error (MAPE)	0.000
Relative Humidity Test forecast model error (%)		Relative Humidity Test forecast model error (%)	
Mean Absolute Error (MAE)	1.800	Mean Absolute Error (MAE)	1.820
Mean Squared Error (MSE)	9.625	Mean Squared Error (MSE)	9.586
Root Mean Squared Error (RMSE)	3.102	Root Mean Squared Error (RMSE)	3.096
Mean Absolute Percentage Error (MAPE)	0.023	Mean Absolute Percentage Error (MAPE)	0.024
u Test forecast model error (m s^{-1})		u Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	0.999	Mean Absolute Error (MAE)	0.964
Mean Squared Error (MSE)	1.800	Mean Squared Error (MSE)	1.765
Root Mean Squared Error (RMSE)	1.342	Root Mean Squared Error (RMSE)	1.328
Mean Absolute Percentage Error (MAPE)	0.888	Mean Absolute Percentage Error (MAPE)	0.879
v Test forecast model error (m s^{-1})		v Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	0.689	Mean Absolute Error (MAE)	0.658
Mean Squared Error (MSE)	0.754	Mean Squared Error (MSE)	0.720
Root Mean Squared Error (RMSE)	0.868	Root Mean Squared Error (RMSE)	0.849
Mean Absolute Percentage Error (MAPE)	0.834	Mean Absolute Percentage Error (MAPE)	0.773

MSE values are squared units.

Table 88. Metrics for Buoy 22 RF Case1 prior 3 6-hr nowcast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

NOWCAST CASE1 NO SCALE PRIOR3		NOWCAST CASE1 SCALE PRIOR3	
Air Temperature 6hr forecast model error (C)		Air Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	0.131	Mean Absolute Error (MAE)	0.836
Mean Squared Error (MSE)	0.020	Mean Squared Error (MSE)	1.859
Root Mean Squared Error (RMSE)	0.142	Root Mean Squared Error (RMSE)	1.363
Mean Absolute Percentage Error (MAPE)	0.007	Mean Absolute Percentage Error (MAPE)	0.046
Water Temperature 6hr forecast model error (C)		Water Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	0.148	Mean Absolute Error (MAE)	0.935
Mean Squared Error (MSE)	0.022	Mean Squared Error (MSE)	1.043
Root Mean Squared Error (RMSE)	0.149	Root Mean Squared Error (RMSE)	1.021
Mean Absolute Percentage Error (MAPE)	0.008	Mean Absolute Percentage Error (MAPE)	0.048
Sea Level Pressure 6hr forecast model error (hPa)		Sea Level Pressure 6hr forecast model error (hPa)	
Mean Absolute Error (MAE)	1.478	Mean Absolute Error (MAE)	2.565
Mean Squared Error (MSE)	3.082	Mean Squared Error (MSE)	10.057
Root Mean Squared Error (RMSE)	1.756	Root Mean Squared Error (RMSE)	3.171
Mean Absolute Percentage Error (MAPE)	0.001	Mean Absolute Percentage Error (MAPE)	0.003
Relative Humidity 6hr forecast model error (%)		Relative Humidity 6hr forecast model error(%)	
Mean Absolute Error (MAE)	6.965	Mean Absolute Error (MAE)	6.880
Mean Squared Error (MSE)	106.747	Mean Squared Error (MSE)	58.807
Root Mean Squared Error (RMSE)	10.332	Root Mean Squared Error (RMSE)	7.669
Mean Absolute Percentage Error (MAPE)	0.087	Mean Absolute Percentage Error (MAPE)	0.089
u 6hr forecast model error (m s^{-1})		u 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	2.452	Mean Absolute Error (MAE)	3.219
Mean Squared Error (MSE)	6.664	Mean Squared Error (MSE)	22.645
Root Mean Squared Error (RMSE)	2.581	Root Mean Squared Error (RMSE)	4.759
Mean Absolute Percentage Error (MAPE)	1.214	Mean Absolute Percentage Error (MAPE)	0.942
v 6hr forecast model error (m s^{-1})		v 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	0.458	Mean Absolute Error (MAE)	1.328
Mean Squared Error (MSE)	0.367	Mean Squared Error (MSE)	3.145
Root Mean Squared Error (RMSE)	0.606	Root Mean Squared Error (RMSE)	1.773
Mean Absolute Percentage Error (MAPE)	0.579	Mean Absolute Percentage Error (MAPE)	1.926

MSE values are squared units.

Table 89. Buoy 22 RF Case1 prior 3 6-hr nowcast no scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-13 00:00:00	18.443183	19.298913	1014.749220	60.816717	1.785503	-0.411193
2017-10-13 01:00:00	18.389267	19.526508	1014.732980	66.106200	2.462628	-0.328749
2017-10-13 02:00:00	18.341033	19.528575	1014.482460	76.852417	4.405932	-0.106473
2017-10-13 03:00:00	18.307033	19.523492	1013.529000	77.466800	4.533432	-0.446487
2017-10-13 04:00:00	18.315750	19.537342	1012.780728	77.214283	4.358544	-0.451317
2017-10-13 05:00:00	18.332700	19.511642	1012.607885	77.018233	3.728171	-0.281348

Table 90. Buoy 22 RF Case1 prior 3 6-hr nowcast scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-13 00:00:00	21.445583	18.786968	1013.558193	71.102467	-4.459195	-0.455181
2017-10-13 01:00:00	19.108717	20.087962	1012.951970	77.685283	-1.065146	-0.209933
2017-10-13 02:00:00	18.226400	19.821210	1011.722100	78.103350	1.930774	1.371337
2017-10-13 03:00:00	18.229967	20.245142	1009.991167	80.199400	2.627195	-4.141716
2017-10-13 04:00:00	18.310067	20.916724	1008.249687	85.176900	2.977227	-2.086877
2017-10-13 05:00:00	18.644200	20.769513	1007.925633	86.428467	2.077623	1.154684

5. BUOY 22 Case 2 RF No Scale/Scale Factor, with prior 3 hours comparison

Table 91. Metrics for Buoy 22 RF Case2 prior 3 test data forecast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

CASE2 NO SCALE PRIOR3		CASE2 SCALE PRIOR3	
Air Temperature Test forecast model error (C)		Air Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	0.294	Mean Absolute Error (MAE)	0.296
Mean Squared Error (MSE)	0.142	Mean Squared Error (MSE)	0.147
Root Mean Squared Error (RMSE)	0.376	Root Mean Squared Error (RMSE)	0.383
Mean Absolute Percentage Error (MAPE)	0.015	Mean Absolute Percentage Error (MAPE)	0.015
Water Temperature Test forecast model error (C)		Water Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	0.066	Mean Absolute Error (MAE)	0.069
Mean Squared Error (MSE)	0.008	Mean Squared Error (MSE)	0.008
Root Mean Squared Error (RMSE)	0.089	Root Mean Squared Error (RMSE)	0.090
Mean Absolute Percentage Error (MAPE)	0.003	Mean Absolute Percentage Error (MAPE)	0.003
Sea Level Pressure Test forecast model error (hPa)		Sea Level Pressure Test forecast model error (hPa)	
Mean Absolute Error (MAE)	0.275	Mean Absolute Error (MAE)	0.283
Mean Squared Error (MSE)	0.115	Mean Squared Error (MSE)	0.121
Root Mean Squared Error (RMSE)	0.338	Root Mean Squared Error (RMSE)	0.348
Mean Absolute Percentage Error (MAPE)	0.000	Mean Absolute Percentage Error (MAPE)	0.000
Relative Humidity Test forecast model error (%)		Relative Humidity Test forecast model error (%)	
Mean Absolute Error (MAE)	2.677	Mean Absolute Error (MAE)	2.702
Mean Squared Error (MSE)	12.968	Mean Squared Error (MSE)	13.875
Root Mean Squared Error (RMSE)	3.601	Root Mean Squared Error (RMSE)	3.725
Mean Absolute Percentage Error (MAPE)	0.037	Mean Absolute Percentage Error (MAPE)	0.038
u Test forecast model error (m s^{-1})		u Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.621	Mean Absolute Error (MAE)	1.637
Mean Squared Error (MSE)	5.855	Mean Squared Error (MSE)	5.902
Root Mean Squared Error (RMSE)	2.420	Root Mean Squared Error (RMSE)	2.429
Mean Absolute Percentage Error (MAPE)	0.579	Mean Absolute Percentage Error (MAPE)	0.624
v Test forecast model error (m s^{-1})		v Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.099	Mean Absolute Error (MAE)	1.121
Mean Squared Error (MSE)	2.628	Mean Squared Error (MSE)	2.719
Root Mean Squared Error (RMSE)	1.621	Root Mean Squared Error (RMSE)	1.649
Mean Absolute Percentage Error (MAPE)	0.913	Mean Absolute Percentage Error (MAPE)	0.899

MSE values are squared units.

Table 92. Metrics for Buoy 22 RF Case2 prior 3 6-hr nowcast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

NOWCAST CASE2 NO SCALE PRIOR3		NOWCAST CASE2 SCALE PRIOR3	
Air Temperature 6hr forecast model error (C)		Air Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	0.955	Mean Absolute Error (MAE)	2.096
Mean Squared Error (MSE)	0.965	Mean Squared Error (MSE)	5.008
Root Mean Squared Error (RMSE)	0.982	Root Mean Squared Error (RMSE)	2.238
Mean Absolute Percentage Error (MAPE)	0.056	Mean Absolute Percentage Error (MAPE)	0.122
Water Temperature 6hr forecast model error (C)		Water Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	0.916	Mean Absolute Error (MAE)	1.826
Mean Squared Error (MSE)	0.883	Mean Squared Error (MSE)	3.663
Root Mean Squared Error (RMSE)	0.940	Root Mean Squared Error (RMSE)	1.914
Mean Absolute Percentage Error (MAPE)	0.050	Mean Absolute Percentage Error (MAPE)	0.100
Sea Level Pressure 6hr forecast model error (hPa)		Sea Level Pressure 6hr forecast model error (hPa)	
Mean Absolute Error (MAE)	2.684	Mean Absolute Error (MAE)	2.934
Mean Squared Error (MSE)	7.337	Mean Squared Error (MSE)	12.014
Root Mean Squared Error (RMSE)	2.709	Root Mean Squared Error (RMSE)	3.466
Mean Absolute Percentage Error (MAPE)	0.003	Mean Absolute Percentage Error (MAPE)	0.003
Relative Humidity 6hr forecast model error (%)		Relative Humidity 6hr forecast model error (%)	
Mean Absolute Error (MAE)	1.387	Mean Absolute Error (MAE)	10.485
Mean Squared Error (MSE)	5.166	Mean Squared Error (MSE)	134.281
Root Mean Squared Error (RMSE)	2.273	Root Mean Squared Error (RMSE)	11.588
Mean Absolute Percentage Error (MAPE)	0.021	Mean Absolute Percentage Error (MAPE)	0.153
u 6hr forecast model error (m s^{-1})		u 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	2.283	Mean Absolute Error (MAE)	4.354
Mean Squared Error (MSE)	6.126	Mean Squared Error (MSE)	21.028
Root Mean Squared Error (RMSE)	2.475	Root Mean Squared Error (RMSE)	4.586
Mean Absolute Percentage Error (MAPE)	1.062	Mean Absolute Percentage Error (MAPE)	1.599
v 6hr forecast model error (m s^{-1})		v 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.293	Mean Absolute Error (MAE)	3.803
Mean Squared Error (MSE)	2.356	Mean Squared Error (MSE)	20.864
Root Mean Squared Error (RMSE)	1.535	Root Mean Squared Error (RMSE)	4.568
Mean Absolute Percentage Error (MAPE)	0.328	Mean Absolute Percentage Error (MAPE)	0.682

MSE values are squared units.

Table 93. Buoy 22 RF Case2 prior 3 6-hr nowcast no scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-21 06:00:00	18.522800	19.698408	1011.326650	69.913083	4.701198	-4.458724
2017-10-21 07:00:00	18.428250	19.514025	1011.119250	70.431667	4.710475	-5.667391
2017-10-21 08:00:00	18.152700	19.244916	1011.131150	70.202100	4.771685	-5.810968
2017-10-21 09:00:00	17.995633	18.987831	1012.047617	69.576400	4.677933	-5.331884
2017-10-21 10:00:00	17.628000	18.803005	1012.207625	69.538700	4.751223	-5.611641
2017-10-21 11:00:00	17.574983	18.776694	1012.835783	69.049117	4.984574	-5.265353

Table 94. Buoy 22 RF Case2 prior 3 6-hr nowcast scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-21 06:00:00	20.929000	21.278723	1010.076423	79.240033	2.606030	0.742166
2017-10-21 07:00:00	19.962633	20.702058	1009.008697	68.409950	4.221637	-0.506141
2017-10-21 08:00:00	19.369750	20.151504	1009.134692	76.701250	4.436647	-1.221231
2017-10-21 09:00:00	18.673167	19.707221	1013.232367	86.554200	-0.342835	0.022518
2017-10-21 10:00:00	18.256117	19.339950	1013.746143	85.104483	-2.075749	-3.250651
2017-10-21 11:00:00	17.958767	19.301434	1016.227150	73.992583	-3.944282	-2.437592

6. BUOY22 Case 3 RF No Scale/Scale Factor, with prior 3 hours comparison

Table 95. Metrics for Buoy 22 RF Case3 prior 3 test data forecast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

CASE3 NO SCALE PRIOR3		CASE3 SCALE PRIOR3	
Air Temperature Test forecast model error (C)		Air Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	1.487	Mean Absolute Error (MAE)	1.493
Mean Squared Error (MSE)	6.418	Mean Squared Error (MSE)	6.457
Root Mean Squared Error (RMSE)	2.533	Root Mean Squared Error (RMSE)	2.541
Mean Absolute Percentage Error (MAPE)	0.060	Mean Absolute Percentage Error (MAPE)	0.060
Water Temperature Test forecast model error (C)		Water Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	0.187	Mean Absolute Error (MAE)	0.193
Mean Squared Error (MSE)	0.075	Mean Squared Error (MSE)	0.079
Root Mean Squared Error (RMSE)	0.273	Root Mean Squared Error (RMSE)	0.280
Mean Absolute Percentage Error (MAPE)	0.010	Mean Absolute Percentage Error (MAPE)	0.010
Sea Level Pressure Test forecast model error (hPa)		Sea Level Pressure Test forecast model error (hPa)	
Mean Absolute Error (MAE)	0.361	Mean Absolute Error (MAE)	0.364
Mean Squared Error (MSE)	0.242	Mean Squared Error (MSE)	0.244
Root Mean Squared Error (RMSE)	0.492	Root Mean Squared Error (RMSE)	0.494
Mean Absolute Percentage Error (MAPE)	0.000	Mean Absolute Percentage Error (MAPE)	0.000
Relative Humidity Test forecast model error (%)		Relative Humidity Test forecast model error (%)	
Mean Absolute Error (MAE)	8.643	Mean Absolute Error (MAE)	8.746
Mean Squared Error (MSE)	170.336	Mean Squared Error (MSE)	176.007
Root Mean Squared Error (RMSE)	13.051	Root Mean Squared Error (RMSE)	13.267
Mean Absolute Percentage Error (MAPE)	0.210	Mean Absolute Percentage Error (MAPE)	0.213
u Test forecast model error ($m\ s^{-1}$)		u Test forecast model error ($m\ s^{-1}$)	
Mean Absolute Error (MAE)	1.676	Mean Absolute Error (MAE)	1.691
Mean Squared Error (MSE)	6.345	Mean Squared Error (MSE)	6.246
Root Mean Squared Error (RMSE)	2.519	Root Mean Squared Error (RMSE)	2.499
Mean Absolute Percentage Error (MAPE)	1.443	Mean Absolute Percentage Error (MAPE)	1.461
v Test forecast model error ($m\ s^{-1}$)		v Test forecast model error ($m\ s^{-1}$)	
Mean Absolute Error (MAE)	1.110	Mean Absolute Error (MAE)	1.098
Mean Squared Error (MSE)	2.580	Mean Squared Error (MSE)	2.544
Root Mean Squared Error (RMSE)	1.606	Root Mean Squared Error (RMSE)	1.595
Mean Absolute Percentage Error (MAPE)	1.024	Mean Absolute Percentage Error (MAPE)	0.892

MSE values are squared units.

Table 96. Metrics for Buoy 22 RF Case3 prior 3 6-hr nowcast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

NOWCAST CASE3 NO SCALE PRIOR3		NOWCAST CASE3 SCALE PRIOR3	
Air Temperature 6hr forecast model error (C)		Air Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	0.329	Mean Absolute Error (MAE)	2.178
Mean Squared Error (MSE)	0.187	Mean Squared Error (MSE)	6.987
Root Mean Squared Error (RMSE)	0.432	Root Mean Squared Error (RMSE)	2.643
Mean Absolute Percentage Error (MAPE)	0.016	Mean Absolute Percentage Error (MAPE)	0.102
Water Temperature 6hr forecast model error (C)		Water Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	1.705	Mean Absolute Error (MAE)	0.715
Mean Squared Error (MSE)	3.096	Mean Squared Error (MSE)	0.578
Root Mean Squared Error (RMSE)	1.760	Root Mean Squared Error (RMSE)	0.760
Mean Absolute Percentage Error (MAPE)	0.086	Mean Absolute Percentage Error (MAPE)	0.036
Sea Level Pressure 6hr forecast model error (hPa)		Sea Level Pressure 6hr forecast model error (hPa)	
Mean Absolute Error (MAE)	0.399	Mean Absolute Error (MAE)	3.013
Mean Squared Error (MSE)	0.295	Mean Squared Error (MSE)	16.103
Root Mean Squared Error (RMSE)	0.543	Root Mean Squared Error (RMSE)	4.013
Mean Absolute Percentage Error (MAPE)	0.000	Mean Absolute Percentage Error (MAPE)	0.003
Relative Humidity 6hr forecast model error (%)		Relative Humidity 6hr forecast model error (%)	
Mean Absolute Error (MAE)	4.123	Mean Absolute Error (MAE)	14.349
Mean Squared Error (MSE)	29.605	Mean Squared Error (MSE)	292.663
Root Mean Squared Error (RMSE)	5.441	Root Mean Squared Error (RMSE)	17.107
Mean Absolute Percentage Error (MAPE)	0.070	Mean Absolute Percentage Error (MAPE)	0.236
u 6hr forecast model error (m s^{-1})		u 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	0.990	Mean Absolute Error (MAE)	2.712
Mean Squared Error (MSE)	2.234	Mean Squared Error (MSE)	11.428
Root Mean Squared Error (RMSE)	1.495	Root Mean Squared Error (RMSE)	3.381
Mean Absolute Percentage Error (MAPE)	1.115	Mean Absolute Percentage Error (MAPE)	2.445
v 6hr forecast model error (m s^{-1})		v 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.833	Mean Absolute Error (MAE)	2.642
Mean Squared Error (MSE)	6.236	Mean Squared Error (MSE)	11.074
Root Mean Squared Error (RMSE)	2.497	Root Mean Squared Error (RMSE)	3.328
Mean Absolute Percentage Error (MAPE)	1.137	Mean Absolute Percentage Error (MAPE)	1.625

MSE values are squared units.

Table 97. Buoy 22 RF Case3 Prior 1 6-hr nowcast no scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-26 03:00:00	21.670583	21.909142	1010.622327	65.769233	0.920747	0.794886
2017-10-26 04:00:00	21.557250	21.902500	1009.516783	61.333500	2.725450	0.856553
2017-10-26 05:00:00	21.537833	21.885525	1009.118008	66.092900	2.656507	-1.695711
2017-10-26 06:00:00	21.524917	21.900292	1009.136733	65.652433	2.072149	-1.871403
2017-10-26 07:00:00	21.448417	21.276683	1009.026522	66.996317	2.000088	-1.964828
2017-10-26 08:00:00	21.386167	20.663417	1009.138583	67.232517	2.730644	-1.795533

Table 98. Buoy 22 RF Case3 Prior 1 6-hr nowcast scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-26 03:00:00	21.394917	20.655529	1017.877408	68.116500	-3.758272	3.214992
2017-10-26 04:00:00	21.369333	20.661788	1013.494917	58.440250	2.362600	0.153356
2017-10-26 05:00:00	20.045500	20.859617	1011.552625	81.472867	3.907742	-2.289910
2017-10-26 06:00:00	18.238167	20.179983	1011.935517	73.228433	-0.092614	-2.901554
2017-10-26 07:00:00	17.861800	19.294575	1009.751675	86.359283	0.828039	-3.243411
2017-10-26 08:00:00	17.052900	18.740563	1010.182275	85.054867	4.971731	-2.463786

E. TENSORFLOW

1. BUOY21 Case 1 TF No Scale/Scale Factor, with prior 3 hours comparison

Table 99. Metrics for Buoy 21 TF Case1 prior 3 test data forecast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

CASE1 NO SCALE PRIOR3		CASE1 SCALE PRIOR3	
Air Temperature Test forecast model error (C)		Air Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	1.027	Mean Absolute Error (MAE)	2.395
Mean Squared Error (MSE)	2.678	Mean Squared Error (MSE)	16.032
Root Mean Squared Error (RMSE)	1.636	Root Mean Squared Error (RMSE)	4.004
Mean Absolute Percentage Error (MAPE)	0.054	Mean Absolute Percentage Error (MAPE)	0.121
Water Temperature Test forecast model error (C)		Water Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	0.408	Mean Absolute Error (MAE)	3.03
Mean Squared Error (MSE)	0.387	Mean Squared Error (MSE)	25.788
Root Mean Squared Error (RMSE)	0.622	Root Mean Squared Error (RMSE)	5.078
Mean Absolute Percentage Error (MAPE)	0.021	Mean Absolute Percentage Error (MAPE)	0.155
Sea Level Pressure Test forecast model error (hPa)		Sea Level Pressure Test forecast model error (hPa)	
Mean Absolute Error (MAE)	1.558	Mean Absolute Error (MAE)	173.758
Mean Squared Error (MSE)	8.191	Mean Squared Error (MSE)	73214.555
Root Mean Squared Error (RMSE)	2.862	Root Mean Squared Error (RMSE)	270.582
Mean Absolute Percentage Error (MAPE)	0.002	Mean Absolute Percentage Error (MAPE)	0.172
Relative Humidity Test forecast model error (%)		Relative Humidity Test forecast model error (%)	
Mean Absolute Error (MAE)	4.285	Mean Absolute Error (MAE)	13.41
Mean Squared Error (MSE)	75.683	Mean Squared Error (MSE)	428.252
Root Mean Squared Error (RMSE)	8.7	Root Mean Squared Error (RMSE)	20.694
Mean Absolute Percentage Error (MAPE)	0.079	Mean Absolute Percentage Error (MAPE)	0.215
u Test forecast model error (m s^{-1})		u Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	2.446	Mean Absolute Error (MAE)	1.812
Mean Squared Error (MSE)	9.555	Mean Squared Error (MSE)	8.387
Root Mean Squared Error (RMSE)	3.091	Root Mean Squared Error (RMSE)	2.896
Mean Absolute Percentage Error (MAPE)	1.318	Mean Absolute Percentage Error (MAPE)	1.612
v Test forecast model error (m s^{-1})		v Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.695	Mean Absolute Error (MAE)	1.933
Mean Squared Error (MSE)	4.097	Mean Squared Error (MSE)	8.459
Root Mean Squared Error (RMSE)	2.024	Root Mean Squared Error (RMSE)	2.909
Mean Absolute Percentage Error (MAPE)	0.921	Mean Absolute Percentage Error (MAPE)	1.203

MSE values are squared units.

Table 100. Metrics for Buoy 21 TF Case1 prior 3 6-hr nowcast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

NOWCAST CASE1 NO SCALE PRIOR3		NOWCAST CASE1 SCALE PRIOR3	
Air Temperature 6hr forecast model error (C)		Air Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	0.284	Mean Absolute Error (MAE)	3.064
Mean Squared Error (MSE)	0.147	Mean Squared Error (MSE)	21.378
Root Mean Squared Error (RMSE)	0.384	Root Mean Squared Error (RMSE)	4.624
Mean Absolute Percentage Error (MAPE)	0.015	Mean Absolute Percentage Error (MAPE)	0.166
Water Temperature 6hr forecast model error (C)		Water Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	0.364	Mean Absolute Error (MAE)	2.982
Mean Squared Error (MSE)	0.181	Mean Squared Error (MSE)	10.568
Root Mean Squared Error (RMSE)	0.425	Root Mean Squared Error (RMSE)	3.251
Mean Absolute Percentage Error (MAPE)	0.018	Mean Absolute Percentage Error (MAPE)	0.15
Sea Level Pressure 6hr forecast model error (hPa)		Sea Level Pressure 6hr forecast model error (hPa)	
Mean Absolute Error (MAE)	1.568	Mean Absolute Error (MAE)	199.926
Mean Squared Error (MSE)	3.769	Mean Squared Error (MSE)	48801.922
Root Mean Squared Error (RMSE)	1.941	Root Mean Squared Error (RMSE)	220.912
Mean Absolute Percentage Error (MAPE)	0.002	Mean Absolute Percentage Error (MAPE)	0.198
Relative Humidity 6hr forecast model error (%)		Relative Humidity 6hr forecast model error(%)	
Mean Absolute Error (MAE)	6.643	Mean Absolute Error (MAE)	17.327
Mean Squared Error (MSE)	53.578	Mean Squared Error (MSE)	771.452
Root Mean Squared Error (RMSE)	7.32	Root Mean Squared Error (RMSE)	27.775
Mean Absolute Percentage Error (MAPE)	0.094	Mean Absolute Percentage Error (MAPE)	0.228
u 6hr forecast model error (m s^{-1})		u 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.924	Mean Absolute Error (MAE)	3.609
Mean Squared Error (MSE)	5.429	Mean Squared Error (MSE)	25.454
Root Mean Squared Error (RMSE)	2.33	Root Mean Squared Error (RMSE)	5.045
Mean Absolute Percentage Error (MAPE)	0.546	Mean Absolute Percentage Error (MAPE)	1.184
v 6hr forecast model error (m s^{-1})		v 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	0.795	Mean Absolute Error (MAE)	2.539
Mean Squared Error (MSE)	1.109	Mean Squared Error (MSE)	8.251
Root Mean Squared Error (RMSE)	1.053	Root Mean Squared Error (RMSE)	2.872
Mean Absolute Percentage Error (MAPE)	1.857	Mean Absolute Percentage Error (MAPE)	3.479

MSE values are squared units.

Table 101. Buoy 21 TF Case1 Prior 1 6-hr nowcast no scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-12 23:52:32	18.202648	19.879824	1014.976868	80.974266	0.972760	-1.997644
2017-10-13 00:52:32	18.665689	20.012365	1014.789429	79.098450	0.839147	-1.708334
2017-10-13 01:52:32	18.790934	20.439066	1013.402954	78.315392	0.884301	-2.099768
2017-10-13 02:52:32	18.641567	20.319508	1013.684326	78.272560	1.169034	-2.703196
2017-10-13 03:52:32	18.658554	20.350626	1012.836304	78.254410	1.216416	-2.691629
2017-10-13 04:52:32	18.662125	20.095045	1012.752258	78.444084	1.324823	-3.099684

Table 102. Buoy 21 TF Case1 Prior 1 6-hr nowcast scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-12 23:52:32	28.588470	24.403412	1402.448730	141.798294	-4.315034	-3.498074
2017-10-13 00:52:32	19.171152	22.468006	1149.019531	85.960495	-3.447471	-1.119763
2017-10-13 01:52:32	17.251284	16.878052	833.711914	68.160583	2.396312	0.229505
2017-10-13 02:52:32	19.922398	19.370312	788.091736	69.478455	1.755448	1.117253
2017-10-13 03:52:32	18.478230	23.196554	917.501526	68.288483	2.128138	0.694644
2017-10-13 04:52:32	23.030607	23.699463	1187.380371	94.427917	4.869039	0.184040

2. BUOY21 Case 2 TF No Scale/Scale Factor, with prior 3 hours comparison

Table 103. Metrics for Buoy 21 TF Case2 prior 3 test data forecast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

CASE2 NO SCALE PRIOR3		CASE2 SCALE PRIOR3	
Air Temperature Test forecast model error (C)		Air Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	1.096	Mean Absolute Error (MAE)	1.990
Mean Squared Error (MSE)	1.706	Mean Squared Error (MSE)	6.491
Root Mean Squared Error (RMSE)	1.306	Root Mean Squared Error (RMSE)	2.548
Mean Absolute Percentage Error (MAPE)	0.056	Mean Absolute Percentage Error (MAPE)	0.104
Water Temperature Test forecast model error (C)		Water Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	0.625	Mean Absolute Error (MAE)	1.770
Mean Squared Error (MSE)	0.793	Mean Squared Error (MSE)	7.183
Root Mean Squared Error (RMSE)	0.890	Root Mean Squared Error (RMSE)	2.680
Mean Absolute Percentage Error (MAPE)	0.033	Mean Absolute Percentage Error (MAPE)	0.094
Sea Level Pressure Test forecast model error (hPa)		Sea Level Pressure Test forecast model error (hPa)	
Mean Absolute Error (MAE)	1.715	Mean Absolute Error (MAE)	87.397
Mean Squared Error (MSE)	5.690	Mean Squared Error (MSE)	14588.355
Root Mean Squared Error (RMSE)	2.385	Root Mean Squared Error (RMSE)	120.782
Mean Absolute Percentage Error (MAPE)	0.002	Mean Absolute Percentage Error (MAPE)	0.086
Relative Humidity Test forecast model error (%)		Relative Humidity Test forecast model error (%)	
Mean Absolute Error (MAE)	4.558	Mean Absolute Error (MAE)	8.729
Mean Squared Error (MSE)	43.912	Mean Squared Error (MSE)	151.974
Root Mean Squared Error (RMSE)	6.627	Root Mean Squared Error (RMSE)	12.328
Mean Absolute Percentage Error (MAPE)	0.067	Mean Absolute Percentage Error (MAPE)	0.123
u Test forecast model error (m s^{-1})		u Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	2.220	Mean Absolute Error (MAE)	2.363
Mean Squared Error (MSE)	7.940	Mean Squared Error (MSE)	9.091
Root Mean Squared Error (RMSE)	2.818	Root Mean Squared Error (RMSE)	3.015
Mean Absolute Percentage Error (MAPE)	0.789	Mean Absolute Percentage Error (MAPE)	1.054
v Test forecast model error (m s^{-1})		v Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.369	Mean Absolute Error (MAE)	1.685
Mean Squared Error (MSE)	3.005	Mean Squared Error (MSE)	4.203
Root Mean Squared Error (RMSE)	1.733	Root Mean Squared Error (RMSE)	2.050
Mean Absolute Percentage Error (MAPE)	1.082	Mean Absolute Percentage Error (MAPE)	0.933

MSE values are squared units.

Table 104. Metrics for Buoy 21 TF Case2 prior 3 6-hr nowcast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

NOWCAST CASE2 NO SCALE PRIOR3			NOWCAST CASE2 SCALE PRIOR3	
Air Temperature 6hr forecast model error (C)			Air Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	4.205		Mean Absolute Error (MAE)	4.510
Mean Squared Error (MSE)	18.172		Mean Squared Error (MSE)	24.460
Root Mean Squared Error (RMSE)	4.263		Root Mean Squared Error (RMSE)	4.946
Mean Absolute Percentage Error (MAPE)	0.273		Mean Absolute Percentage Error (MAPE)	0.288
Water Temperature 6hr forecast model error (C)			Water Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	5.290		Mean Absolute Error (MAE)	5.420
Mean Squared Error (MSE)	28.098		Mean Squared Error (MSE)	32.375
Root Mean Squared Error (RMSE)	5.301		Root Mean Squared Error (RMSE)	5.690
Mean Absolute Percentage Error (MAPE)	0.354		Mean Absolute Percentage Error (MAPE)	0.363
Sea Level Pressure 6hr forecast model error (hPa)			Sea Level Pressure 6hr forecast model error (hPa)	
Mean Absolute Error (MAE)	5.509		Mean Absolute Error (MAE)	61.233
Mean Squared Error (MSE)	31.646		Mean Squared Error (MSE)	5598.900
Root Mean Squared Error (RMSE)	5.625		Root Mean Squared Error (RMSE)	74.826
Mean Absolute Percentage Error (MAPE)	0.005		Mean Absolute Percentage Error (MAPE)	0.060
Relative Humidity 6hr forecast model error (%)			Relative Humidity 6hr forecast model error(%)	
Mean Absolute Error (MAE)	4.861		Mean Absolute Error (MAE)	10.374
Mean Squared Error (MSE)	39.081		Mean Squared Error (MSE)	188.113
Root Mean Squared Error (RMSE)	6.251		Root Mean Squared Error (RMSE)	13.715
Mean Absolute Percentage Error (MAPE)	0.064		Mean Absolute Percentage Error (MAPE)	0.146
u 6hr forecast model error (m s^{-1})			u 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	2.861		Mean Absolute Error (MAE)	2.451
Mean Squared Error (MSE)	10.669		Mean Squared Error (MSE)	9.131
Root Mean Squared Error (RMSE)	3.266		Root Mean Squared Error (RMSE)	3.022
Mean Absolute Percentage Error (MAPE)	22.390		Mean Absolute Percentage Error (MAPE)	5.856
v 6hr forecast model error (m s^{-1})			v 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	2.209		Mean Absolute Error (MAE)	1.726
Mean Squared Error (MSE)	5.873		Mean Squared Error (MSE)	4.652
Root Mean Squared Error (RMSE)	2.423		Root Mean Squared Error (RMSE)	2.157
Mean Absolute Percentage Error (MAPE)	0.602		Mean Absolute Percentage Error (MAPE)	0.443

MSE values are squared units.

Table 105. Buoy 21 TF Case2 Prior 1 6-hr nowcast no scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-21 05:52:48	19.600729	20.320309	1007.994141	77.410706	4.868820	-5.679758
2017-10-21 06:52:48	19.959631	20.384052	1006.413391	75.234985	5.194592	-5.870481
2017-10-21 07:52:48	20.162436	20.389076	1009.222595	72.890350	5.451653	-5.653533
2017-10-21 08:52:48	19.915579	20.359638	1009.646179	70.741356	5.405998	-6.103345
2017-10-21 09:52:48	19.634832	20.192589	1009.695007	66.890427	5.317944	-6.844507
2017-10-21 10:52:48	19.356527	19.694767	1010.834290	69.541725	4.867966	-6.970954

Table 106. Buoy 21 TF Case2 Prior 1 6-hr nowcast scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-21 05:52:48	24.816805	22.001200	948.442322	95.196785	5.566193	-3.045881
2017-10-21 06:52:48	21.029697	21.018301	1042.180420	88.819252	3.508944	-1.538604
2017-10-21 07:52:48	18.526819	19.673765	988.798950	76.906059	3.693287	-3.860128
2017-10-21 08:52:48	20.170841	17.194981	954.252869	76.771828	-2.099467	-1.274460
2017-10-21 09:52:48	18.576256	22.345009	1051.893921	78.226837	-1.220356	-6.203048
2017-10-21 10:52:48	17.341774	19.888256	1166.177734	86.565239	-4.058237	-4.229343

3. BUOY21 Case 3 TF No Scale/Scale Factor, with prior 3 hours comparison

Table 107. Metrics for Buoy 21 TF Case3 prior 3 test data forecast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

CASE3 NO SCALE PRIOR3	
Air Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	3.462
Mean Squared Error (MSE)	19.619
Root Mean Squared Error (RMSE)	4.429
Mean Absolute Percentage Error (MAPE)	0.150
Water Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	3.428
Mean Squared Error (MSE)	14.594
Root Mean Squared Error (RMSE)	3.820
Mean Absolute Percentage Error (MAPE)	0.211
Sea Level Pressure Test forecast model error (hPa)	
Mean Absolute Error (MAE)	11.378
Mean Squared Error (MSE)	190.034
Root Mean Squared Error (RMSE)	13.785
Mean Absolute Percentage Error (MAPE)	0.011
Relative Humidity Test forecast model error (%)	
Mean Absolute Error (MAE)	9.151
Mean Squared Error (MSE)	156.327
Root Mean Squared Error (RMSE)	12.503
Mean Absolute Percentage Error (MAPE)	0.288
u Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	2.471
Mean Squared Error (MSE)	9.921
Root Mean Squared Error (RMSE)	3.150
Mean Absolute Percentage Error (MAPE)	1.682
v Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	2.378
Mean Squared Error (MSE)	7.785
Root Mean Squared Error (RMSE)	2.790
Mean Absolute Percentage Error (MAPE)	1.958

CASE3 SCALE PRIOR3	
Air Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	3.276
Mean Squared Error (MSE)	15.520
Root Mean Squared Error (RMSE)	3.940
Mean Absolute Percentage Error (MAPE)	0.163
Water Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	3.072
Mean Squared Error (MSE)	14.067
Root Mean Squared Error (RMSE)	3.751
Mean Absolute Percentage Error (MAPE)	0.190
Sea Level Pressure Test forecast model error (hPa)	
Mean Absolute Error (MAE)	250.182
Mean Squared Error (MSE)	93442.820
Root Mean Squared Error (RMSE)	305.684
Mean Absolute Percentage Error (MAPE)	0.246
Relative Humidity Test forecast model error (%)	
Mean Absolute Error (MAE)	30.414
Mean Squared Error (MSE)	1388.053
Root Mean Squared Error (RMSE)	37.257
Mean Absolute Percentage Error (MAPE)	0.911
u Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	4.831
Mean Squared Error (MSE)	40.230
Root Mean Squared Error (RMSE)	6.343
Mean Absolute Percentage Error (MAPE)	2.355
v Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	3.065
Mean Squared Error (MSE)	15.570
Root Mean Squared Error (RMSE)	3.946
Mean Absolute Percentage Error (MAPE)	1.373

MSE values are squared units.

Table 108. Metrics for Buoy 21 TF Case3 prior 3 6-hr nowcast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

NOWCAST CASE3 NO SCALE PRIOR3		NOWCAST CASE3 SCALE PRIOR3	
Air Temperature 6hr forecast model error (C)		Air Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	0.761	Mean Absolute Error (MAE)	2.419
Mean Squared Error (MSE)	0.675	Mean Squared Error (MSE)	8.297
Root Mean Squared Error (RMSE)	0.821	Root Mean Squared Error (RMSE)	2.880
Mean Absolute Percentage Error (MAPE)	0.036	Mean Absolute Percentage Error (MAPE)	0.116
Water Temperature 6hr forecast model error (C)		Water Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	0.672	Mean Absolute Error (MAE)	0.979
Mean Squared Error (MSE)	0.517	Mean Squared Error (MSE)	1.377
Root Mean Squared Error (RMSE)	0.719	Root Mean Squared Error (RMSE)	1.174
Mean Absolute Percentage Error (MAPE)	0.034	Mean Absolute Percentage Error (MAPE)	0.049
Sea Level Pressure 6hr forecast model error (hPa)		Sea Level Pressure 6hr forecast model error (hPa)	
Mean Absolute Error (MAE)	4.526	Mean Absolute Error (MAE)	103.349
Mean Squared Error (MSE)	21.507	Mean Squared Error (MSE)	15525.979
Root Mean Squared Error (RMSE)	4.638	Root Mean Squared Error (RMSE)	124.603
Mean Absolute Percentage Error (MAPE)	0.004	Mean Absolute Percentage Error (MAPE)	0.102
Relative Humidity 6hr forecast model error (%)		Relative Humidity 6hr forecast model error(%)	
Mean Absolute Error (MAE)	7.151	Mean Absolute Error (MAE)	31.436
Mean Squared Error (MSE)	56.786	Mean Squared Error (MSE)	1169.658
Root Mean Squared Error (RMSE)	7.536	Root Mean Squared Error (RMSE)	34.200
Mean Absolute Percentage Error (MAPE)	0.122	Mean Absolute Percentage Error (MAPE)	0.542
u 6hr forecast model error (m s^{-1})		u 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.602	Mean Absolute Error (MAE)	4.481
Mean Squared Error (MSE)	6.310	Mean Squared Error (MSE)	26.124
Root Mean Squared Error (RMSE)	2.512	Root Mean Squared Error (RMSE)	5.111
Mean Absolute Percentage Error (MAPE)	0.910	Mean Absolute Percentage Error (MAPE)	5.378
v 6hr forecast model error (m s^{-1})		v 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	2.597	Mean Absolute Error (MAE)	2.930
Mean Squared Error (MSE)	11.229	Mean Squared Error (MSE)	13.260
Root Mean Squared Error (RMSE)	3.351	Root Mean Squared Error (RMSE)	3.641
Mean Absolute Percentage Error (MAPE)	0.842	Mean Absolute Percentage Error (MAPE)	0.943

MSE values are squared units.

Table 109. Buoy 21 TF Case3 Prior 1 6-hr nowcast no scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-26 03:52:45	21.010668	19.950552	1006.489685	65.588554	-1.177155	-1.699772
2017-10-26 04:52:45	20.997797	20.653025	1004.461426	64.397491	1.438830	-0.589076
2017-10-26 05:52:45	20.953341	20.796953	1003.375854	65.348007	0.880780	-1.658484
2017-10-26 06:52:45	20.918655	20.395678	1004.846497	61.876915	1.441697	-1.753337
2017-10-26 07:52:45	20.465939	20.251265	1005.168884	63.729866	1.734187	-1.704831
2017-10-26 08:52:45	20.159742	19.816896	1003.843201	65.036774	0.615104	-4.238244

Table 110. Buoy 21 TF Case3 Prior 1 6-hr nowcast scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-26 03:52:45	24.471735	22.429499	1248.617554	110.689217	-0.186947	-3.439560
2017-10-26 04:52:45	22.498257	20.248407	1085.600708	96.238319	4.006684	-1.437644
2017-10-26 05:52:45	17.960510	20.427393	1060.780396	96.222404	-8.030916	-7.261679
2017-10-26 06:52:45	20.160545	18.709208	1114.845337	73.816216	-4.489575	-3.543161
2017-10-26 07:52:45	15.623599	18.304144	1134.994995	86.810646	-0.090232	-8.824541
2017-10-26 08:52:45	25.387890	19.632357	1030.597290	83.041100	0.859654	-3.447059

4. BUOY22 Case 1 TF No Scale/Scale Factor, with prior 3 hours comparison

Table 111. Metrics for Buoy 22 TF Case1 prior 3 test data forecast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

CASE1 NO SCALE PRIOR3			CASE1 SCALE PRIOR3	
Air Temperature Test forecast model error (C)			Air Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	0.856		Mean Absolute Error (MAE)	1.767
Mean Squared Error (MSE)	1.044		Mean Squared Error (MSE)	5.386
Root Mean Squared Error (RMSE)	1.022		Root Mean Squared Error (RMSE)	2.321
Mean Absolute Percentage Error (MAPE)	0.047		Mean Absolute Percentage Error (MAPE)	0.095
Water Temperature Test forecast model error (C)			Water Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	0.934		Mean Absolute Error (MAE)	2.956
Mean Squared Error (MSE)	1.080		Mean Squared Error (MSE)	13.228
Root Mean Squared Error (RMSE)	1.039		Root Mean Squared Error (RMSE)	3.637
Mean Absolute Percentage Error (MAPE)	0.048		Mean Absolute Percentage Error (MAPE)	0.150
Sea Level Pressure Test forecast model error (hPa)			Sea Level Pressure Test forecast model error (hPa)	
Mean Absolute Error (MAE)	2.319		Mean Absolute Error (MAE)	167.060
Mean Squared Error (MSE)	7.835		Mean Squared Error (MSE)	40548.544
Root Mean Squared Error (RMSE)	2.799		Root Mean Squared Error (RMSE)	201.367
Mean Absolute Percentage Error (MAPE)	0.002		Mean Absolute Percentage Error (MAPE)	0.165
Relative Humidity Test forecast model error (%)			Relative Humidity Test forecast model error (%)	
Mean Absolute Error (MAE)	2.432		Mean Absolute Error (MAE)	10.722
Mean Squared Error (MSE)	11.832		Mean Squared Error (MSE)	171.883
Root Mean Squared Error (RMSE)	3.440		Root Mean Squared Error (RMSE)	13.110
Mean Absolute Percentage Error (MAPE)	0.032		Mean Absolute Percentage Error (MAPE)	0.136
u Test forecast model error (m s^{-1})			u Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	0.964		Mean Absolute Error (MAE)	1.648
Mean Squared Error (MSE)	1.534		Mean Squared Error (MSE)	3.764
Root Mean Squared Error (RMSE)	1.239		Root Mean Squared Error (RMSE)	1.940
Mean Absolute Percentage Error (MAPE)	0.840		Mean Absolute Percentage Error (MAPE)	1.237
v Test forecast model error (m s^{-1})			v Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	0.746		Mean Absolute Error (MAE)	1.619
Mean Squared Error (MSE)	1.008		Mean Squared Error (MSE)	5.050
Root Mean Squared Error (RMSE)	1.004		Root Mean Squared Error (RMSE)	2.247
Mean Absolute Percentage Error (MAPE)	1.143		Mean Absolute Percentage Error (MAPE)	2.110

MSE values are squared units.

Table 112. Metrics for Buoy 22 TF Case1 prior 3 6-hr nowcast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

NOWCAST CASE1 NO SCALE PRIOR3		NOWCAST CASE1 SCALE PRIOR3	
Air Temperature 6hr forecast model error (C)		Air Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	1.148	Mean Absolute Error (MAE)	3.345
Mean Squared Error (MSE)	1.524	Mean Squared Error (MSE)	17.976
Root Mean Squared Error (RMSE)	1.235	Root Mean Squared Error (RMSE)	4.240
Mean Absolute Percentage Error (MAPE)	0.063	Mean Absolute Percentage Error (MAPE)	0.182
Water Temperature 6hr forecast model error (C)		Water Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	1.824	Mean Absolute Error (MAE)	2.527
Mean Squared Error (MSE)	3.372	Mean Squared Error (MSE)	13.524
Root Mean Squared Error (RMSE)	1.836	Root Mean Squared Error (RMSE)	3.678
Mean Absolute Percentage Error (MAPE)	0.094	Mean Absolute Percentage Error (MAPE)	0.130
Sea Level Pressure 6hr forecast model error (hPa)		Sea Level Pressure 6hr forecast model error (hPa)	
Mean Absolute Error (MAE)	4.804	Mean Absolute Error (MAE)	213.310
Mean Squared Error (MSE)	24.247	Mean Squared Error (MSE)	71604.433
Root Mean Squared Error (RMSE)	4.924	Root Mean Squared Error (RMSE)	267.590
Mean Absolute Percentage Error (MAPE)	0.005	Mean Absolute Percentage Error (MAPE)	0.211
Relative Humidity 6hr forecast model error (%)		Relative Humidity 6hr forecast model error(%)	
Mean Absolute Error (MAE)	3.549	Mean Absolute Error (MAE)	13.847
Mean Squared Error (MSE)	13.676	Mean Squared Error (MSE)	243.669
Root Mean Squared Error (RMSE)	3.698	Root Mean Squared Error (RMSE)	15.610
Mean Absolute Percentage Error (MAPE)	0.046	Mean Absolute Percentage Error (MAPE)	0.178
u 6hr forecast model error (m s^{-1})		u 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	2.716	Mean Absolute Error (MAE)	2.986
Mean Squared Error (MSE)	8.926	Mean Squared Error (MSE)	12.707
Root Mean Squared Error (RMSE)	2.988	Root Mean Squared Error (RMSE)	3.565
Mean Absolute Percentage Error (MAPE)	1.390	Mean Absolute Percentage Error (MAPE)	1.115
v 6hr forecast model error (m s^{-1})		v 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	0.742	Mean Absolute Error (MAE)	1.182
Mean Squared Error (MSE)	0.839	Mean Squared Error (MSE)	1.707
Root Mean Squared Error (RMSE)	0.916	Root Mean Squared Error (RMSE)	1.306
Mean Absolute Percentage Error (MAPE)	1.325	Mean Absolute Percentage Error (MAPE)	2.325

MSE values are squared units.

Table 113. Buoy 22 TF Case1 Prior 1 6-hr nowcast no scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-13 00:00:00	20.022318	21.356953	1006.525269	77.193192	0.887721	0.456004
2017-10-13 01:00:00	19.922115	21.476688	1006.105347	76.601654	2.277766	-0.006131
2017-10-13 02:00:00	19.665768	21.431210	1006.829224	76.972374	3.941480	-0.524591
2017-10-13 03:00:00	19.339825	21.224594	1008.066895	78.210373	4.491735	-0.878068
2017-10-13 04:00:00	19.042276	20.998398	1009.128418	79.459221	4.584201	-0.991872
2017-10-13 05:00:00	18.926964	20.830372	1010.166931	80.286247	4.507773	-1.106443

Table 114. Buoy 22 TF Case1 Prior 1 6-hr nowcast scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-13 00:00:00	26.266834	27.786573	1555.958984	102.298561	-1.161097	1.328380
2017-10-13 01:00:00	19.304882	21.409349	1144.462036	100.745216	0.657991	-2.332708
2017-10-13 02:00:00	20.140848	18.736494	948.350342	84.229179	0.403365	-2.281070
2017-10-13 03:00:00	12.874383	20.065792	744.232117	59.378792	3.080734	-1.671638
2017-10-13 04:00:00	17.440247	18.308861	835.476379	75.903603	3.995905	-1.141019
2017-10-13 05:00:00	20.957722	21.780012	1107.187866	92.530922	2.701655	1.288877

5. BUOY22 Case 2 TF No Scale/Scale Factor, with prior 3 hours comparison

Table 115. Metrics for Buoy 22 TF Case2 prior 3 test data forecast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

CASE2 NO SCALE PRIOR3		CASE2 SCALE PRIOR3	
Air Temperature Test forecast model error (C)		Air Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	0.761	Mean Absolute Error (MAE)	2.059
Mean Squared Error (MSE)	0.891	Mean Squared Error (MSE)	7.152
Root Mean Squared Error (RMSE)	0.944	Root Mean Squared Error (RMSE)	2.674
Mean Absolute Percentage Error (MAPE)	0.039	Mean Absolute Percentage Error (MAPE)	0.105
Water Temperature Test forecast model error (C)		Water Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	0.320	Mean Absolute Error (MAE)	1.474
Mean Squared Error (MSE)	0.154	Mean Squared Error (MSE)	3.589
Root Mean Squared Error (RMSE)	0.393	Root Mean Squared Error (RMSE)	1.894
Mean Absolute Percentage Error (MAPE)	0.016	Mean Absolute Percentage Error (MAPE)	0.072
Sea Level Pressure Test forecast model error (hPa)		Sea Level Pressure Test forecast model error (hPa)	
Mean Absolute Error (MAE)	4.568	Mean Absolute Error (MAE)	85.711
Mean Squared Error (MSE)	34.492	Mean Squared Error (MSE)	14678.290
Root Mean Squared Error (RMSE)	5.873	Root Mean Squared Error (RMSE)	121.154
Mean Absolute Percentage Error (MAPE)	0.005	Mean Absolute Percentage Error (MAPE)	0.085
Relative Humidity Test forecast model error (%)		Relative Humidity Test forecast model error (%)	
Mean Absolute Error (MAE)	3.523	Mean Absolute Error (MAE)	11.741
Mean Squared Error (MSE)	22.381	Mean Squared Error (MSE)	334.279
Root Mean Squared Error (RMSE)	4.731	Root Mean Squared Error (RMSE)	18.283
Mean Absolute Percentage Error (MAPE)	0.050	Mean Absolute Percentage Error (MAPE)	0.163
u Test forecast model error (m s^{-1})		u Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.011	Mean Absolute Error (MAE)	1.694
Mean Squared Error (MSE)	1.723	Mean Squared Error (MSE)	5.063
Root Mean Squared Error (RMSE)	1.313	Root Mean Squared Error (RMSE)	2.250
Mean Absolute Percentage Error (MAPE)	0.471	Mean Absolute Percentage Error (MAPE)	0.966
v Test forecast model error (m s^{-1})		v Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.301	Mean Absolute Error (MAE)	1.396
Mean Squared Error (MSE)	3.211	Mean Squared Error (MSE)	3.671
Root Mean Squared Error (RMSE)	1.792	Root Mean Squared Error (RMSE)	1.916
Mean Absolute Percentage Error (MAPE)	2.445	Mean Absolute Percentage Error (MAPE)	1.876

MSE values are squared units.

Table 116. Metrics for Buoy 22 TF Case2 prior 3 6-hr nowcast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

NOWCAST CASE2 NO SCALE PRIOR3		NOWCAST CASE2 SCALE PRIOR3	
Air Temperature 6hr forecast model error (C)		Air Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	3.140	Mean Absolute Error (MAE)	4.534
Mean Squared Error (MSE)	9.992	Mean Squared Error (MSE)	31.205
Root Mean Squared Error (RMSE)	3.161	Root Mean Squared Error (RMSE)	5.586
Mean Absolute Percentage Error (MAPE)	0.184	Mean Absolute Percentage Error (MAPE)	0.269
Water Temperature 6hr forecast model error (C)		Water Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	1.776	Mean Absolute Error (MAE)	3.786
Mean Squared Error (MSE)	3.167	Mean Squared Error (MSE)	18.439
Root Mean Squared Error (RMSE)	1.780	Root Mean Squared Error (RMSE)	4.294
Mean Absolute Percentage Error (MAPE)	0.097	Mean Absolute Percentage Error (MAPE)	0.207
Sea Level Pressure 6hr forecast model error (hPa)		Sea Level Pressure 6hr forecast model error (hPa)	
Mean Absolute Error (MAE)	13.638	Mean Absolute Error (MAE)	141.312
Mean Squared Error (MSE)	188.102	Mean Squared Error (MSE)	33731.814
Root Mean Squared Error (RMSE)	13.715	Root Mean Squared Error (RMSE)	183.662
Mean Absolute Percentage Error (MAPE)	0.013	Mean Absolute Percentage Error (MAPE)	0.139
Relative Humidity 6hr forecast model error (%)		Relative Humidity 6hr forecast model error(%)	
Mean Absolute Error (MAE)	4.311	Mean Absolute Error (MAE)	17.311
Mean Squared Error (MSE)	23.894	Mean Squared Error (MSE)	395.174
Root Mean Squared Error (RMSE)	4.888	Root Mean Squared Error (RMSE)	19.879
Mean Absolute Percentage Error (MAPE)	0.064	Mean Absolute Percentage Error (MAPE)	0.255
u 6hr forecast model error (m s^{-1})		u 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	5.253	Mean Absolute Error (MAE)	4.049
Mean Squared Error (MSE)	29.613	Mean Squared Error (MSE)	19.726
Root Mean Squared Error (RMSE)	5.442	Root Mean Squared Error (RMSE)	4.441
Mean Absolute Percentage Error (MAPE)	2.255	Mean Absolute Percentage Error (MAPE)	1.601
v 6hr forecast model error (m s^{-1})		v 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	2.259	Mean Absolute Error (MAE)	3.533
Mean Squared Error (MSE)	7.247	Mean Squared Error (MSE)	15.137
Root Mean Squared Error (RMSE)	2.692	Root Mean Squared Error (RMSE)	3.891
Mean Absolute Percentage Error (MAPE)	0.607	Mean Absolute Percentage Error (MAPE)	0.696

MSE values are squared units.

Table 117. Buoy 22 TF Case2 Prior 1 6-hr nowcast no scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-21 06:00:00	20.658535	20.319740	1002.839844	73.117462	10.899295	-5.688303
2017-10-21 07:00:00	20.289429	20.145912	1001.619507	72.491096	11.316249	-6.955560
2017-10-21 08:00:00	20.065800	20.109657	1000.242920	72.048988	11.293483	-7.189981
2017-10-21 09:00:00	20.127876	20.019356	999.797058	72.969978	10.747630	-6.949892
2017-10-21 10:00:00	20.247074	19.910812	999.799683	73.470680	9.636134	-7.309076
2017-10-21 11:00:00	20.026615	19.675262	1000.650818	73.191727	8.650439	-7.493333

Table 118. Buoy 22 TF Case2 Prior 1 6-hr nowcast scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-21 06:00:00	24.496305	25.044840	1240.252930	95.531525	6.586473	-3.110273
2017-10-21 07:00:00	19.375515	19.079287	887.041931	74.389809	3.262253	-1.094322
2017-10-21 08:00:00	16.830872	19.971857	928.727234	73.343925	0.601769	-1.780507
2017-10-21 09:00:00	20.147295	23.557659	973.405701	88.701027	0.594502	-0.535001
2017-10-21 10:00:00	21.340784	22.871641	1027.551514	88.960785	0.252338	-8.574626
2017-10-21 11:00:00	26.499104	21.720003	1369.669434	94.362701	-4.563703	-2.892857

6. BUOY22 Case 3 TF No Scale/Scale Factor, with prior 3 hours comparison

Table 119. Metrics for Buoy 22 TF Case3 prior 3 test data forecast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

CASE3 NO SCALE PRIOR3		CASE3 SCALE PRIOR3	
Air Temperature Test forecast model error (C)		Air Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	2.030	Mean Absolute Error (MAE)	4.680
Mean Squared Error (MSE)	5.759	Mean Squared Error (MSE)	34.988
Root Mean Squared Error (RMSE)	2.400	Root Mean Squared Error (RMSE)	5.915
Mean Absolute Percentage Error (MAPE)	0.101	Mean Absolute Percentage Error (MAPE)	0.216
Water Temperature Test forecast model error (C)		Water Temperature Test forecast model error (C)	
Mean Absolute Error (MAE)	0.664	Mean Absolute Error (MAE)	4.928
Mean Squared Error (MSE)	0.699	Mean Squared Error (MSE)	57.423
Root Mean Squared Error (RMSE)	0.836	Root Mean Squared Error (RMSE)	7.578
Mean Absolute Percentage Error (MAPE)	0.034	Mean Absolute Percentage Error (MAPE)	0.246
Sea Level Pressure Test forecast model error (hPa)		Sea Level Pressure Test forecast model error (hPa)	
Mean Absolute Error (MAE)	3.441	Mean Absolute Error (MAE)	184.912
Mean Squared Error (MSE)	16.354	Mean Squared Error (MSE)	72899.290
Root Mean Squared Error (RMSE)	4.044	Root Mean Squared Error (RMSE)	269.999
Mean Absolute Percentage Error (MAPE)	0.003	Mean Absolute Percentage Error (MAPE)	0.182
Relative Humidity Test forecast model error (%)		Relative Humidity Test forecast model error (%)	
Mean Absolute Error (MAE)	4.589	Mean Absolute Error (MAE)	24.726
Mean Squared Error (MSE)	49.064	Mean Squared Error (MSE)	1158.240
Root Mean Squared Error (RMSE)	7.005	Root Mean Squared Error (RMSE)	34.033
Mean Absolute Percentage Error (MAPE)	0.100	Mean Absolute Percentage Error (MAPE)	0.557
u Test forecast model error (m s^{-1})		u Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.434	Mean Absolute Error (MAE)	2.638
Mean Squared Error (MSE)	3.916	Mean Squared Error (MSE)	11.517
Root Mean Squared Error (RMSE)	1.979	Root Mean Squared Error (RMSE)	3.394
Mean Absolute Percentage Error (MAPE)	2.673	Mean Absolute Percentage Error (MAPE)	3.047
v Test forecast model error (m s^{-1})		v Test forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.359	Mean Absolute Error (MAE)	1.875
Mean Squared Error (MSE)	3.282	Mean Squared Error (MSE)	5.336
Root Mean Squared Error (RMSE)	1.812	Root Mean Squared Error (RMSE)	2.310
Mean Absolute Percentage Error (MAPE)	2.176	Mean Absolute Percentage Error (MAPE)	1.715

MSE values are squared units.

Table 120. Metrics for Buoy 22 TF Case3 prior 3 6-hr nowcast no scale (left panel), and Scale factor (right panel). Adapted from CASPER West data.

NOWCAST CASE3 NO SCALE PRIOR3		NOWCAST CASE3 SCALE PRIOR3	
Air Temperature 6hr forecast model error (C)		Air Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	0.530	Mean Absolute Error (MAE)	1.823
Mean Squared Error (MSE)	0.565	Mean Squared Error (MSE)	6.471
Root Mean Squared Error (RMSE)	0.752	Root Mean Squared Error (RMSE)	2.544
Mean Absolute Percentage Error (MAPE)	0.025	Mean Absolute Percentage Error (MAPE)	0.086
Water Temperature 6hr forecast model error (C)		Water Temperature 6hr forecast model error (C)	
Mean Absolute Error (MAE)	0.293	Mean Absolute Error (MAE)	2.603
Mean Squared Error (MSE)	0.124	Mean Squared Error (MSE)	13.476
Root Mean Squared Error (RMSE)	0.352	Root Mean Squared Error (RMSE)	3.671
Mean Absolute Percentage Error (MAPE)	0.015	Mean Absolute Percentage Error (MAPE)	0.131
Sea Level Pressure 6hr forecast model error (hPa)		Sea Level Pressure 6hr forecast model error (hPa)	
Mean Absolute Error (MAE)	0.860	Mean Absolute Error (MAE)	91.458
Mean Squared Error (MSE)	1.128	Mean Squared Error (MSE)	14625.527
Root Mean Squared Error (RMSE)	1.062	Root Mean Squared Error (RMSE)	120.936
Mean Absolute Percentage Error (MAPE)	0.001	Mean Absolute Percentage Error (MAPE)	0.091
Relative Humidity 6hr forecast model error (%)		Relative Humidity 6hr forecast model error(%)	
Mean Absolute Error (MAE)	4.174	Mean Absolute Error (MAE)	24.084
Mean Squared Error (MSE)	23.921	Mean Squared Error (MSE)	617.994
Root Mean Squared Error (RMSE)	4.891	Root Mean Squared Error (RMSE)	24.859
Mean Absolute Percentage Error (MAPE)	0.067	Mean Absolute Percentage Error (MAPE)	0.386
u 6hr forecast model error (m s^{-1})		u 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	1.021	Mean Absolute Error (MAE)	2.296
Mean Squared Error (MSE)	2.396	Mean Squared Error (MSE)	12.049
Root Mean Squared Error (RMSE)	1.548	Root Mean Squared Error (RMSE)	3.471
Mean Absolute Percentage Error (MAPE)	1.161	Mean Absolute Percentage Error (MAPE)	2.530
v 6hr forecast model error (m s^{-1})		v 6hr forecast model error (m s^{-1})	
Mean Absolute Error (MAE)	2.017	Mean Absolute Error (MAE)	2.258
Mean Squared Error (MSE)	6.291	Mean Squared Error (MSE)	7.114
Root Mean Squared Error (RMSE)	2.508	Root Mean Squared Error (RMSE)	2.667
Mean Absolute Percentage Error (MAPE)	1.395	Mean Absolute Percentage Error (MAPE)	1.654

MSE values are squared units.

Table 121. Buoy 22 TF Case3 Prior 1 6-hr nowcast no scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-26 03:00:00	22.605804	20.678217	1011.432556	58.293858	2.208883	1.045788
2017-10-26 04:00:00	22.034149	20.122805	1009.994385	59.425457	2.143076	-0.355670
2017-10-26 05:00:00	21.795280	19.960484	1009.925293	60.815929	2.481070	-2.015674
2017-10-26 06:00:00	21.852386	20.295872	1009.061646	62.105579	2.608418	-2.397228
2017-10-26 07:00:00	21.634537	19.995464	1008.432922	63.140820	2.273842	-2.921772
2017-10-26 08:00:00	21.353584	20.012192	1008.020203	63.629658	2.941603	-2.492576

Table 122. Buoy 22 TF Case3 Prior 1 6-hr nowcast scale. Adapted from CASPER West data.

date	Air Temperature (C)	Water Temperature (C)	Sea Level Pressure (hPa)	Relative Humidity (%)	u (m/s)	v (m/s)
2017-10-26 03:00:00	26.527357	27.846962	1258.425049	101.043144	-0.245850	-2.285284
2017-10-26 04:00:00	22.149990	23.676235	1125.520630	79.343124	1.652821	-0.395295
2017-10-26 05:00:00	21.958368	20.742775	988.563843	86.857010	3.024729	-1.781424
2017-10-26 06:00:00	19.713051	19.577694	1028.919678	73.199493	2.254956	-0.449835
2017-10-26 07:00:00	20.008221	18.881712	1055.644043	85.892334	5.215961	-6.617807
2017-10-26 08:00:00	19.736570	21.784395	1106.166748	91.003494	6.785488	-2.517065

F. PERSISTENCE FORECAST

1. Buoy 21 Case 1

Table 123. Buoy 21 Case 1 persistence forecast metrics.

CASE 1	
Air Temperature (C) persistence model error	
Mean Absolute Error (MAE)	0.633
Mean Squared Error (MSE)	0.443
Root Mean Squared Error (RMSE)	0.666
Mean Absolute Percentage Error (MAPE)	0.034
Water Temperature (C) persistence model error	
Mean Absolute Error (MAE)	0.177
Mean Squared Error (MSE)	0.033
Root Mean Squared Error (RMSE)	0.181
Mean Absolute Percentage Error (MAPE)	0.009
Sea Level Pressure (hPa) persistence model error	
Mean Absolute Error (MAE)	1.407
Mean Squared Error (MSE)	2.072
Root Mean Squared Error (RMSE)	1.439
Mean Absolute Percentage Error (MAPE)	0.001
Relative Humidity (%) persistence model error	
Mean Absolute Error (MAE)	3.500
Mean Squared Error (MSE)	16.603
Root Mean Squared Error (RMSE)	4.075
Mean Absolute Percentage Error (MAPE)	0.048
u ($m\ s^{-1}$) persistence model error	
Mean Absolute Error (MAE)	0.902
Mean Squared Error (MSE)	1.393
Root Mean Squared Error (RMSE)	1.180
Mean Absolute Percentage Error (MAPE)	0.244
v ($m\ s^{-1}$) persistence model error	
Mean Absolute Error (MAE)	0.686
Mean Squared Error (MSE)	0.540
Root Mean Squared Error (RMSE)	0.735
Mean Absolute Percentage Error (MAPE)	3.650

MSE values are squared units.

2. Buoy 21 Case 2

Table 124. Buoy 21 Case 2 persistence forecast metrics.

CASE 2	
Air Temperature (C) persistence model error	
Mean Absolute Error (MAE)	1.067
Mean Squared Error (MSE)	1.280
Root Mean Squared Error (RMSE)	1.131
Mean Absolute Percentage Error (MAPE)	0.065
Water Temperature (C) persistence model error	
Mean Absolute Error (MAE)	0.893
Mean Squared Error (MSE)	0.894
Root Mean Squared Error (RMSE)	0.945
Mean Absolute Percentage Error (MAPE)	0.060
Sea Level Pressure (hPa) persistence model error	
Mean Absolute Error (MAE)	2.090
Mean Squared Error (MSE)	5.071
Root Mean Squared Error (RMSE)	2.252
Mean Absolute Percentage Error (MAPE)	0.002
Relative Humidity (%) persistence model error	
Mean Absolute Error (MAE)	3.717
Mean Squared Error (MSE)	17.912
Root Mean Squared Error (RMSE)	4.232
Mean Absolute Percentage Error (MAPE)	0.051
u ($m\ s^{-1}$) persistence model error	
Mean Absolute Error (MAE)	3.720
Mean Squared Error (MSE)	19.733
Root Mean Squared Error (RMSE)	4.442
Mean Absolute Percentage Error (MAPE)	0.958
v ($m\ s^{-1}$) persistence model error	
Mean Absolute Error (MAE)	1.139
Mean Squared Error (MSE)	2.100
Root Mean Squared Error (RMSE)	1.449
Mean Absolute Percentage Error (MAPE)	0.197

MSE values are squared units.

3. Buoy 21 Case 3

Table 125. Buoy 21 Case 3 persistence forecast metrics.

CASE 3	
Air Temperature (C) persistence model error	
Mean Absolute Error (MAE)	0.900
Mean Squared Error (MSE)	1.060
Root Mean Squared Error (RMSE)	1.030
Mean Absolute Percentage Error (MAPE)	0.041
Water Temperature (C) persistence model error	
Mean Absolute Error (MAE)	0.310
Mean Squared Error (MSE)	0.135
Root Mean Squared Error (RMSE)	0.367
Mean Absolute Percentage Error (MAPE)	0.015
Sea Level Pressure (hPa) persistence model error	
Mean Absolute Error (MAE)	0.112
Mean Squared Error (MSE)	0.036
Root Mean Squared Error (RMSE)	0.191
Mean Absolute Percentage Error (MAPE)	0.000
Relative Humidity (%) persistence model error	
Mean Absolute Error (MAE)	4.217
Mean Squared Error (MSE)	23.352
Root Mean Squared Error (RMSE)	4.832
Mean Absolute Percentage Error (MAPE)	0.068
u ($m\ s^{-1}$) persistence model error	
Mean Absolute Error (MAE)	0.922
Mean Squared Error (MSE)	0.896
Root Mean Squared Error (RMSE)	0.947
Mean Absolute Percentage Error (MAPE)	1.333
v ($m\ s^{-1}$) persistence model error	
Mean Absolute Error (MAE)	2.538
Mean Squared Error (MSE)	7.498
Root Mean Squared Error (RMSE)	2.738
Mean Absolute Percentage Error (MAPE)	0.898

MSE values are squared units.

4. Buoy 22 Case 1

Table 126. Buoy 22 Case 1 persistence forecast metrics.

CASE 1	
Air Temperature (C) persistence model error	
Mean Absolute Error (MAE)	0.181
Mean Squared Error (MSE)	0.047
Root Mean Squared Error (RMSE)	0.217
Mean Absolute Percentage Error (MAPE)	0.01
Water Temperature (C) persistence model error	
Mean Absolute Error (MAE)	0.054
Mean Squared Error (MSE)	0.003
Root Mean Squared Error (RMSE)	0.059
Mean Absolute Percentage Error (MAPE)	0.003
Sea Level Pressure (hPa) persistence model error	
Mean Absolute Error (MAE)	1.207
Mean Squared Error (MSE)	1.564
Root Mean Squared Error (RMSE)	1.251
Mean Absolute Percentage Error (MAPE)	0.001
Relative Humidity (%) persistence model error	
Mean Absolute Error (MAE)	4.265
Mean Squared Error (MSE)	22.363
Root Mean Squared Error (RMSE)	4.729
Mean Absolute Percentage Error (MAPE)	0.053
u ($m\ s^{-1}$) persistence model error	
Mean Absolute Error (MAE)	0.702
Mean Squared Error (MSE)	1.132
Root Mean Squared Error (RMSE)	1.064
Mean Absolute Percentage Error (MAPE)	0.192
v ($m\ s^{-1}$) persistence model error	
Mean Absolute Error (MAE)	0.467
Mean Squared Error (MSE)	0.282
Root Mean Squared Error (RMSE)	0.531
Mean Absolute Percentage Error (MAPE)	1.03

MSE values are squared units.

5. Buoy 22 Case 2

Table 127. Buoy 22 Case 2 persistence forecast metrics.

CASE 2	
Air Temperature (C) persistence model error	
Mean Absolute Error (MAE)	0.11
Mean Squared Error (MSE)	0.046
Root Mean Squared Error (RMSE)	0.214
Mean Absolute Percentage Error (MAPE)	0.006
Water Temperature (C) persistence model error	
Mean Absolute Error (MAE)	0.454
Mean Squared Error (MSE)	0.253
Root Mean Squared Error (RMSE)	0.503
Mean Absolute Percentage Error (MAPE)	0.025
Sea Level Pressure (hPa) persistence model error	
Mean Absolute Error (MAE)	1.484
Mean Squared Error (MSE)	2.478
Root Mean Squared Error (RMSE)	1.574
Mean Absolute Percentage Error (MAPE)	0.001
Relative Humidity (%) persistence model error	
Mean Absolute Error (MAE)	1.887
Mean Squared Error (MSE)	4.357
Root Mean Squared Error (RMSE)	2.087
Mean Absolute Percentage Error (MAPE)	0.027
u ($m\ s^{-1}$) persistence model error	
Mean Absolute Error (MAE)	3.955
Mean Squared Error (MSE)	18.112
Root Mean Squared Error (RMSE)	4.256
Mean Absolute Percentage Error (MAPE)	0.776
v ($m\ s^{-1}$) persistence model error	
Mean Absolute Error (MAE)	1.946
Mean Squared Error (MSE)	5.066
Root Mean Squared Error (RMSE)	2.251
Mean Absolute Percentage Error (MAPE)	0.406

MSE values are squared units.

6. Buoy 22 Case 3

Table 128. Buoy 22 Case 3 persistence forecast metrics.

CASE 3	
Air Temperature (C) persistence model error	
Mean Absolute Error (MAE)	0.465
Mean Squared Error (MSE)	0.285
Root Mean Squared Error (RMSE)	0.534
Mean Absolute Percentage Error (MAPE)	0.022
Water Temperature (C) persistence model error	
Mean Absolute Error (MAE)	0.396
Mean Squared Error (MSE)	0.162
Root Mean Squared Error (RMSE)	0.402
Mean Absolute Percentage Error (MAPE)	0.02
Sea Level Pressure (hPa) persistence model error	
Mean Absolute Error (MAE)	0.113
Mean Squared Error (MSE)	0.036
Root Mean Squared Error (RMSE)	0.189
Mean Absolute Percentage Error (MAPE)	0
Relative Humidity (%) persistence model error	
Mean Absolute Error (MAE)	6.511
Mean Squared Error (MSE)	59.277
Root Mean Squared Error (RMSE)	7.699
Mean Absolute Percentage Error (MAPE)	0.11
u ($m\ s^{-1}$) persistence model error	
Mean Absolute Error (MAE)	0.62
Mean Squared Error (MSE)	1.026
Root Mean Squared Error (RMSE)	1.013
Mean Absolute Percentage Error (MAPE)	0.714
v ($m\ s^{-1}$) persistence model error	
Mean Absolute Error (MAE)	1.043
Mean Squared Error (MSE)	1.921
Root Mean Squared Error (RMSE)	1.386
Mean Absolute Percentage Error (MAPE)	1.052

MSE values are squared units.

G. ALGORITHM TIMINGS

Table 129. Algorithm timing for all cases.

		Linear Regression	Decision Tree	Random Forest	TensorFlow
Buoy 21 Case 1	No scale	18 s	22 s	23 s	369 s (< 7 min)
	Scale	27 s	23 s	35 s	338 s (< 6 min)
Buoy 21 Case 2	No scale	24 s	27 s	26 s	420 s (7 min)
	Scale	26 s	24 s	26 s	371 s (< 7 min)
Buoy 21 Case 3	No scale	23 s	21 s	26 s	367 s (< 7 min)
	Scale	22 s	20 s	25 s	345 s (< 6 min)
Buoy 22 Case 1	No scale	19 s	21 s	28 s	312 s (< 6 min)
	Scale	20 s	20 s	23 s	355 s (< 6 min)
Buoy 22 Case 2	No scale	19 s	21 s	24 s	239 s (< 4 min)
	Scale	19 s	18 s	24 s	235 s (< 4 min)
Buoy 22 Case 3	No scale	18 s	21 s	24 s	297 s (< 5 min)
	Scale	19 s	20 s	23 s	337 s (< 6 min)
Operating System macOS Big Sur version 11.4					
MacBook Pro (Retina, 13-inch, Mid 2014)					
Processor 2.8 GHz Dual-Core Intel Core i5					
Memory 8 GB 1600 MHz DDR3					
Graphics Intel Iris 1536 MB					

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